1980

Molluscan paleontology of the Pliocene Peace Valley "beds" and Ridge Route "formation" (Ridge Basin group), Ridge Basin, southern California

Daniel R. Young
University of North Dakota

MOLLUSCAN PALEONTOLOGY OF THE PLIOCENE PEACE VALLEY "BEDS" AND RIDGE ROUTE "FORMATION" (RIDGE BASIN GROUP), RIDGE BASIN, SOUTHERN CALIFORNIA

by
Daniel R. Young

Bachelor of Arts, Humboldt State University, 1976

A Thesis

Submitted to the Graduate Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master of Arts

Grand Forks, North Dakota

December
1980

This thesis submitted by Daniel R. Young in partial fulfillment of the requirements for the Degree of Master of Arts from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

Alan M. Cvancara
(Chairman)

F. D. Holland Jr.

John R. Reid

This thesis meets the standards for appearance and conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

Dean of the Graduate School

Permission

Title MOLLUSCAN PALEONTOLOGY OF THE PLIOCENE PEACE VALLEY "BEDS" AND RIDGE ROUTE "FORMATION" (RIDGE BASIN GROUP), RIDGE BASIN, SOUTHERN CALIFORNIA

Department Geology

Degree Master of Arts

In presenting this thesis in partial fulfillment of the requirements for a graduate degree from the University of North Dakota, I agree that the Library of this University shall make it freely available for inspection. I further agree that permission for extensive copying for scholarly purposes may be granted by the professor who supervised my thesis work or, in his absence, by the Chairman of the Department or the Dean of the Graduate School. It is understood that any copying or publication or other use of this thesis or part thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to the University of North Dakota in any scholarly use which may be made of any material in my thesis.

Signature Dal R. Yong

Date September 8, 1980

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Figure

Plate

LIST OF TABLES

ACKNOWLEDGMENTS

Gratitude is expressed to Dr. Robert Osborne, University of Southern California, for unofficially serving and helping as a committee member, and for several field checks. I also thank Andrew Harper for collecting fossils for me from his measured sections and sharing his field information. Diane Hudson provided field assistance during the summer of 1978.

Dr. Edward Wilson, Curator of Invertebrate Paleontology at the Los Angeles County Museum of Natural History, kindly provided work space and equipment for fossil preparation, valuable advice, and a repository for the fossils I studied. Dr. Richard Squires, California State University at Northridge, donated his collection of Ridge Basin molluscs and Dr. Richard Forester, United States Geological Survey, identified and evaluated the ostracodes. Dr. John Crowell, University of California, Santa Barbara, allowed use of his unpublished Ridge Basin map.

I wish to express my appreciation to the many librarians at the University of North Dakota for obtaining and providing research material over extended periods of time. Laramie Winczewski introduced me to the use of a computer and corrected my programs.

I especially wish to thank Dr. Alan Cvancara for serving as committee chairman, his patience, guidance, and his valuable criticism. I also wish to thank Drs. John Reid, F. D. Holland, Jr., and Robert

Osborne for reading this manuscript and offering helpful suggestions. Dr. Lee Gerhard, State Geologist of North Dakota and Department Chairman at the University of North Dakota, provided much appreciated extra office space. I also wish to extend thanks to Joyce Pierson for typing early drafts of this manuscript and providing personal support.

Thanks are extended to the many people who have assisted my research related to the Ridge Basin, including those who have provided lodging. James McIntyre and Andrew Harper obtained airplanes for aerial photography and reconnaissance of the basin. I would like to thank Martin Link for suggesting this project, his encouragement, use of his field notes and air photos, and all of the other useful information that he has provided. I wish to thank my dearest grandmother, Reva Cohen, for financing this project.

ABSTRACT

The Ridge Basin, 90 km northwest of Los Angeles, California, lies within the San Gabriel, San Andreas, Liebre, and Clearwater fault zones. The basin is an elongated, wedge-shaped, intermontane, Miocene-Pliocene basin filled with about 12 000 m of marine, lacustrine, fluvial, and alluvial sediment. More than half of the thickness of the Ridge Route "formation" and about one fifth of the Peace Valley "beds" was examined for molluscs along the northeastern side of the basin and more than 600 m of section were measured.

The nonmarine molluscs of the Ridge Route "formation" and Peace Valley "beds" consist of ten species: one unionid, Anodonta oregonensis (Lea); three sphaeriids, Musculium lacustre (Müller), M. transversum (Say), and Pisidium (Cyclocalyx) nitidum Jenyns; four hydrobiids, Fontelicella aff. F. (F.) truckeensis Yen, Tryonia aff. T. protea Gould, and Hydrobiidae species 1 and 2; one lymnaeid, ?Stagnicola sp.; and one planorbid, ?Planorbula aff. P. armigera (Say).

All of the hydrobiids occur stratigraphically in the lower portion of the Ridge Route "formation" and Peace Valley "beds." The other nonmarine molluscs occur in the Ridge Route "formation" and Peace Valley "beds" above the hydrobiids except in measured section 3, where Fontelicella aff. F. (F.) truckeensis and Hydrobiidae species 2 are associated with Musculium lacustre, M. transversum, and ?Planorbula aff. P. armigera.

Freshwater environments are indicated by the presence of Anodonta Musculium, Pisidium, Fontelicella, ?Stagnicola, and ?Planorbula, whereas brackish water environments may be indicated by Tryonia or hydrobiids. Tryonia aff. T. protea is interpreted to tolerate a wide salinity range. Stagnant water is indicated by Stagnicola and Planorbula. Shallow freshwater is suggested by ?Planorbula aff. P. armigera or Pisidium (Cyclocalyx) nitidum. ?Stagnicola, together with ?Planorbula aff. P. armigera, is assumed to represent shallow ponds or marshes on a floodplain.

Ridge Basin molluscs occur in sediment ranging from claystone to conglomerate although the majority of the molluscan fauna is found in siltstone, very fine-grained wacke, and claystone. The lack of molluscs in the mudstone of the lower Peace Valley "beds" (lacustrine facies), and the presence of the fauna in the nearly stratigraphic equivalent sandstone and siltstone units of the Ridge Route "formation" (fluvial-deltaic facies), may suggest fluctuating salinities in the lacustrine environment with penecontemporaneous stable salinity conditions in the fluvial-deltaic environment. Deep water, high turbidity with sediment influx, or reducing conditions are alternative explanations for the paucity of molluscs.

Ridge Basin nonmarine molluscs do not suggest an age for the basin. Chlamys (Chlamys) cf. C. (C.) hodgei suggests a Miocene or later age for the lowermost Ridge Route "formation" (Wilson 1978). The ostracodes probably indicate a late Miocene age for the lower Ridge Basin Group; however, recent magnetostratigraphy suggests an early Pliocene age for the lowermost Ridge Basin Group (Ensley and Verosub 1979).

INTRODUCTION

General

Purpose.--The Ridge Basin of Southern California has been studied since 1937; most of the research has been directed towards an understanding of the sedimentologic and tectonic evolution of the basin. Little attention has been given to the nonmarine Mollusca, although they may be of value in deciphering paleoenvironments, facies, and stratigraphy. It is the purpose of this paper to identify and illustrate the molluscs of the lower Ridge Basin Group, and to attempt to determine the molluscan paleoecology. A secondary objective is to interpret the paleoenvironments of the lower Ridge Basin Group based on the molluscs, in conjunction with other paleontologic and stratigraphic information.

Area of study.--The Ridge Basin is 90 kilometres northwest of Los Angeles, California, within the San Gabriel, San Andreas, Liebre, and Clearwater fault zones (Figures 1 and 2). The actual area covered by this study includes the southern and eastern portions of the Ridge Route "formation" (quotes emphasize informal usage of stratigraphic names) and Peace Valley "beds" (Figures 5 and 6) represented by the shaded area of Figure 2. These strata are relatively well exposed along road cuts and are easily accessible by car (Figure 3).

Specific areas investigated for molluscan fossils are (refer to Plate 2 for locations and Figure 5 for geological formations): (1) the Cienaga Canyon telephone road; (2) the Old Ridge Route; (3) the Templin

Fig. 1. Index map showing location of study area within the Ridge Basin, California, and major faults. Ridge Basin is the area between the San Gabriel and San Andreas fault zones.

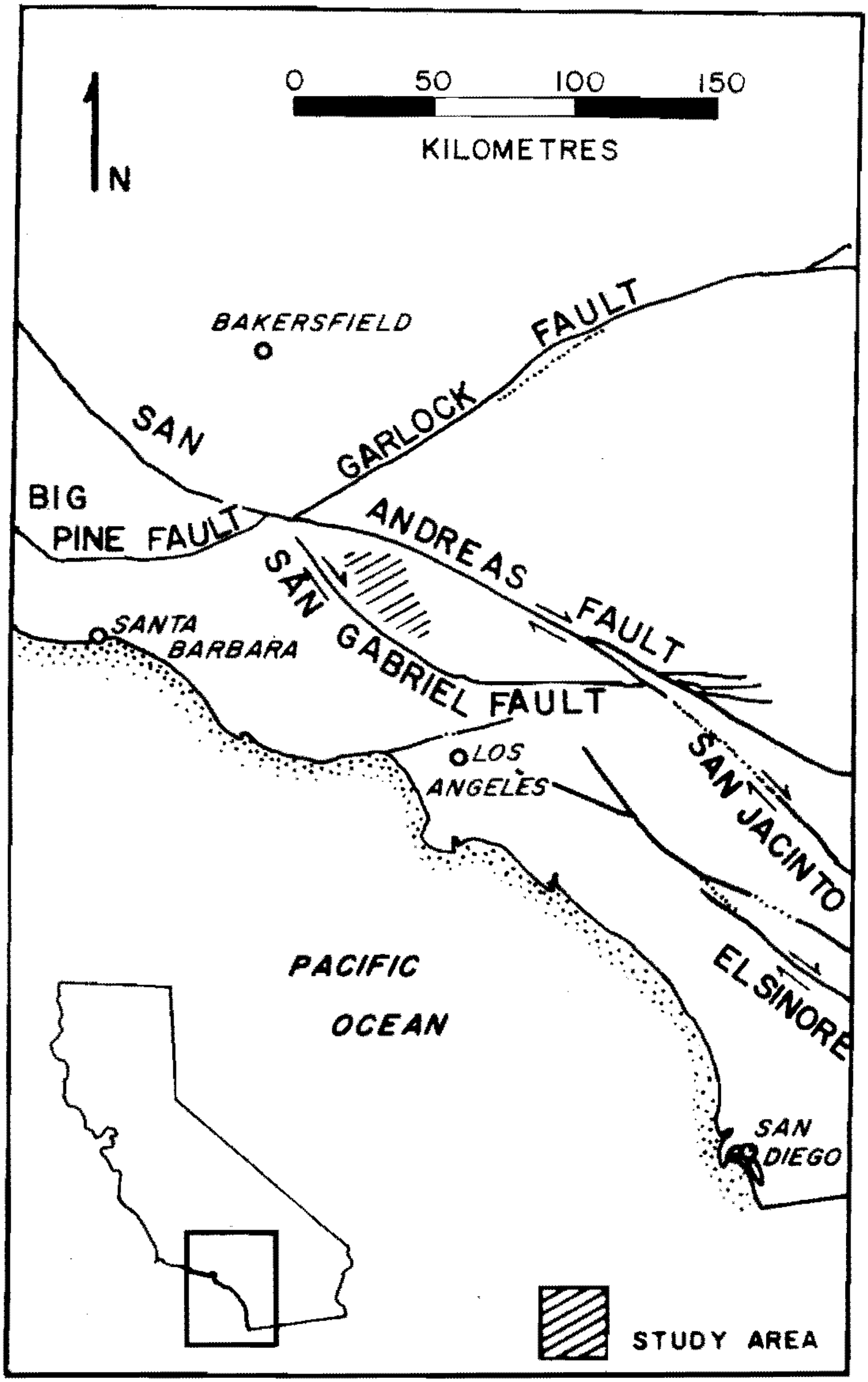
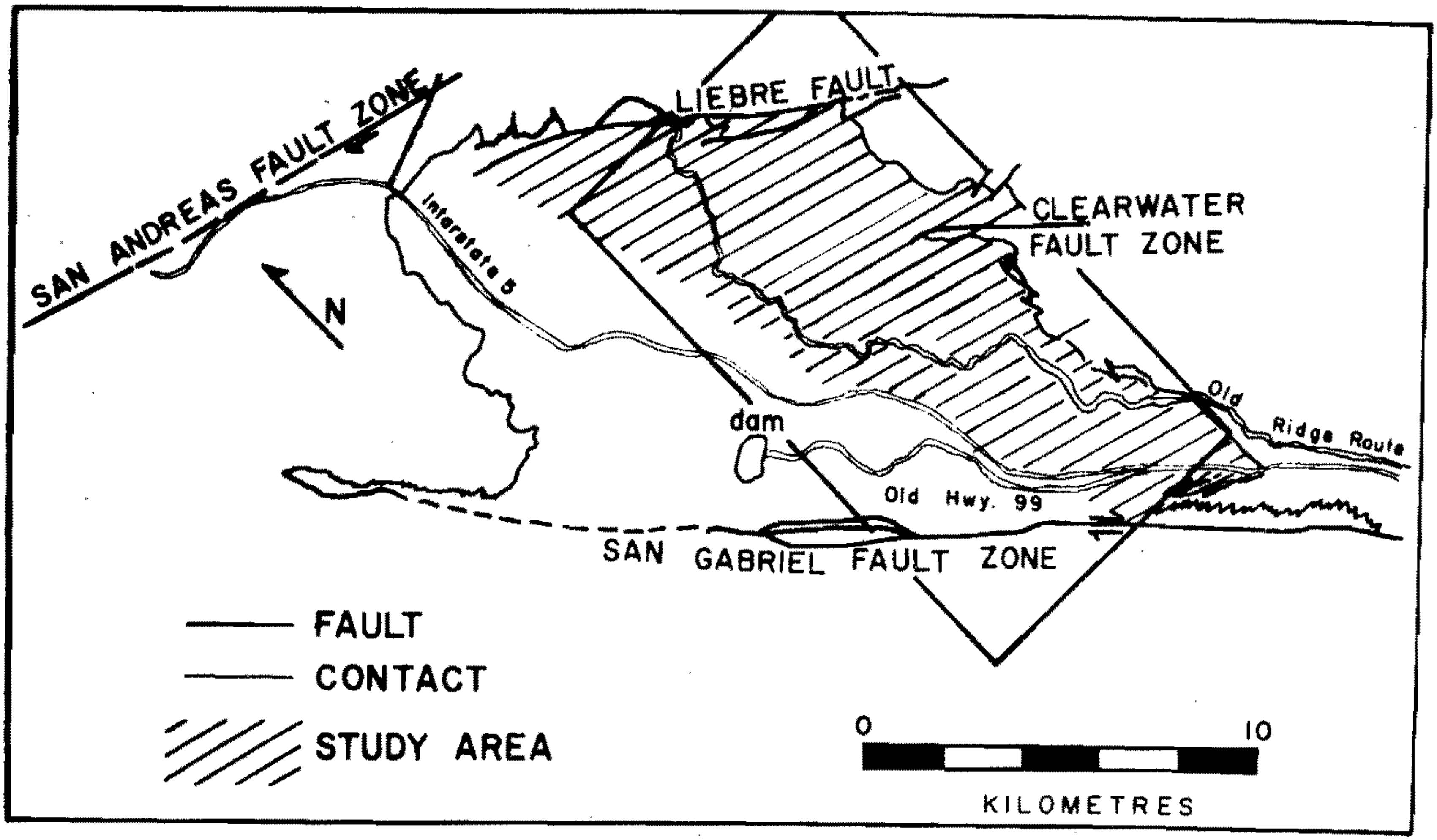
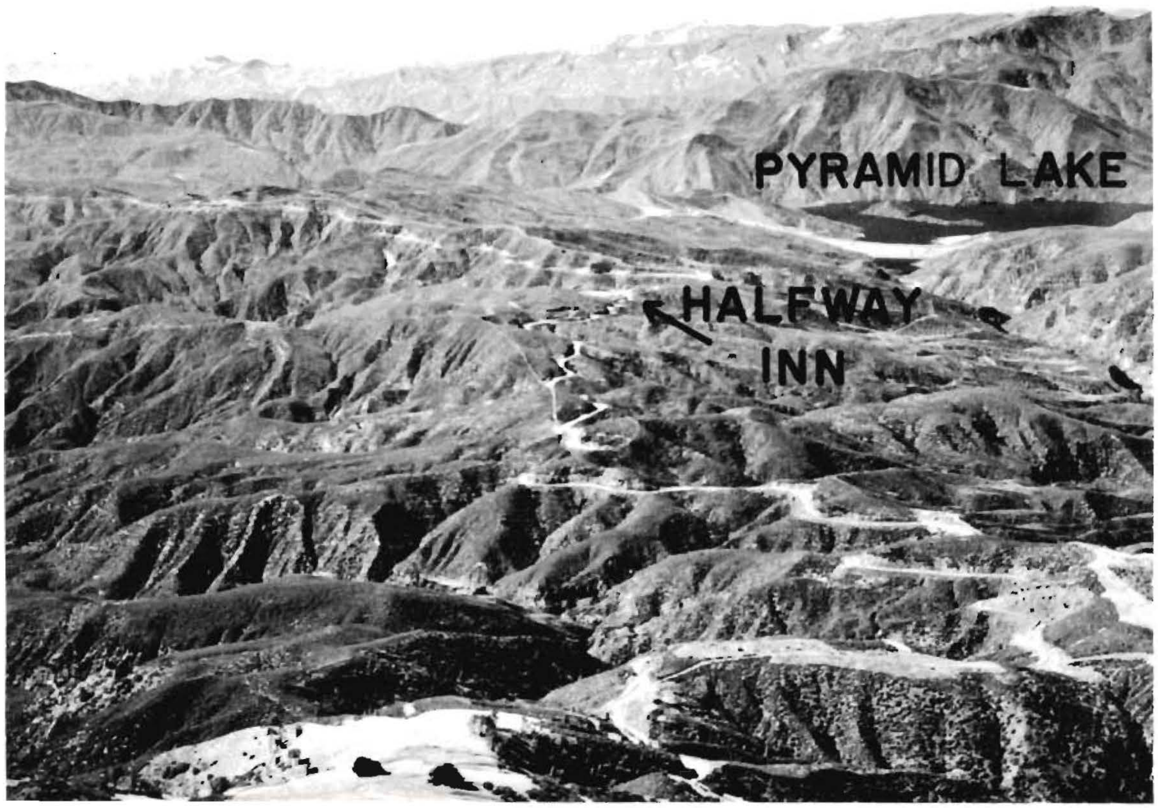

0
50
100
150
KILOMETRES
N
BAKERSFIELD
SAN
GARLOCK
FAULT
BIG
PINE FAULT
ANDREAS
FAULT
SAN
GABRIEL FAULT
SANTA
BARBARA
LOS
ANGELES
SAN JACINTO
ELSINORE
PACIFIC
OCEAN
SAN
DIEGO
STUDY AREA

Fig. 2. Index map of study area, Plate 2 (rectangular area), and geologic map (Figure 5). "Contact" represents the geographic extent of the lower Ridge Basin Group (excluding the Hungry Valley Formation).



SAN ANDREAS FAULT ZONE
LIEBRE FAULT
CLEARWATER FAULT ZONE
Interstate 5
N
dam
Old Ridge Route
Old Hwy. 99
SAN GABRIEL FAULT ZONE
FAULT
CONTACT
STUDY AREA
0
10
KILOMETRES

Fig. 3. Color infrared oblique aerial photograph showing the terrain of Los Angeles County Museum of Natural History-Invertebrate Paleontology (LACMNH) collecting localities 5730 to 5741 and measured sections 12 to 18. View is south 30° west from West Liebre Lookout. Refer to Plate 2 for map locations of collecting localities, measured sections, and Halfway Inn. The Old Ridge Route appears diagonally from the lower right hand corner to the upper left hand corner of the photograph.


PYRAMID LAKE
HALFWAY
INN

Highway; (4) the old Highway 99 south of Templin Highway including the fire lookout road to the southwest; (5) the sandstone member of the Ridge Route "formation" studied by Harper (1978-1980) along interstate 5 and in the northeastern portion of the basin; and (6) various other localities along old Highway 99 and seldom used unpaved roads near the above areas.

GEOLOGIC SETTING

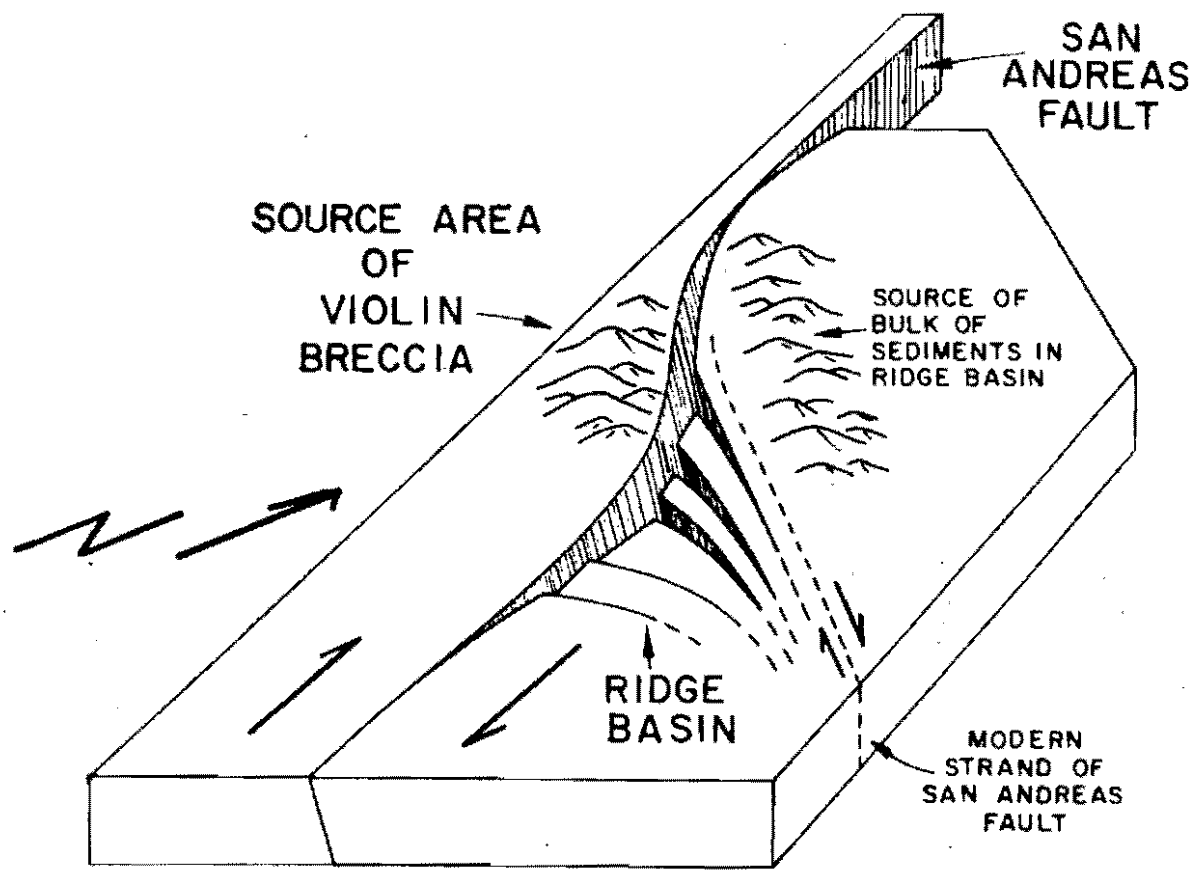
Regional structural setting.--The Ridge Basin is in the Transverse Ranges of Southern California; these ranges have undergone intense folding and faulting during the Pleistocene (Oakeshott 1971).

The Ridge Basin is an elongated, wedge-shaped, late Tertiary, intermontane basin filled with marine, lacustrine, fluvial, and alluvial sediment. The basin is bounded by the San Gabriel fault zone on the southwest and the San Andreas and Liebre fault zones on the north and east (Figure 2).

The San Gabriel fault zone was the active trace of the San Andreas during the late Miocene through Pliocene. This right lateral fault zone can be represented by two blocks moving past each other along a gentle double bend on the fault. The block to the southwest was compressed and uplifted on the restraining bend creating the source area for the Violin Breccia (Figure 4). The block on the northeast was stretched, forming a narrow subsiding trough (the Ridge Basin) parallel to the San Gabriel fault zone at the releasing bend (Crowell 1973, 1974, 1975).

According to Crowell (1975), the right lateral movement on the San Gabriel fault zone continued for several million years with lateral displacement of about 60 km. The basin filled with sediment from an uplifted source area to the northeast. The source area remained stationary and the Ridge Basin, bounded by the San Gabriel fault zone on the southwest, migrated northward towards the source area (Crowell 1974). The source area was uplifted during the late Tertiary along the Liebre,

Fig. 4. Diagrammatic illustration of the origin of the Ridge Basin (modified from Crowell 1974, p. 299).



SAN
ANDREAS
FAULT
SOURCE AREA
OF
VIOLIN
BRECCIA
SOURCE OF
BULK OF
SEDIMENTS IN
RIDGE BASIN
RIDGE
BASIN
MODERN
STRAND OF
SAN ANDREAS
FAULT

Clearwater and other faults (Crowell 1973). Deposition and deformation were penecontemporaneous in the basin. The San Gabriel fault zone became inactive during the Pleistocene as indicated by the fluvial strata of the Pleistocene Hungry Valley Formation that are not offset where they overlie the San Gabriel fault zone. The basin was folded and uplifted during the Quaternary, leaving a nearly continuous record of Pliocene sediment exposed (Crowell 1973).

Regional stratigraphic setting.--The Ridge Basin Group nonconformably overlies Mesozoic granitic and gneissic rocks in the north, and is in fault contact with these basement rocks on the west (Figure 5). The Paleocene-Eocene marine San Francisquito Formation nonconformably overlies these basement rocks south of the Clearwater fault zone and is, in turn, unconformably overlain by the Miocene Mint Canyon Formation (Figure 6). The Mint Canyon Formation is overlain by the late Miocene marine Castaic Formation, the oldest deposits in the Ridge Basin.

Fig. 5. Generalized geologic map of the Ridge Basin, California (modified after Crowell 1954, 1975, and an unpublished map, and Link and Osborne 1978).

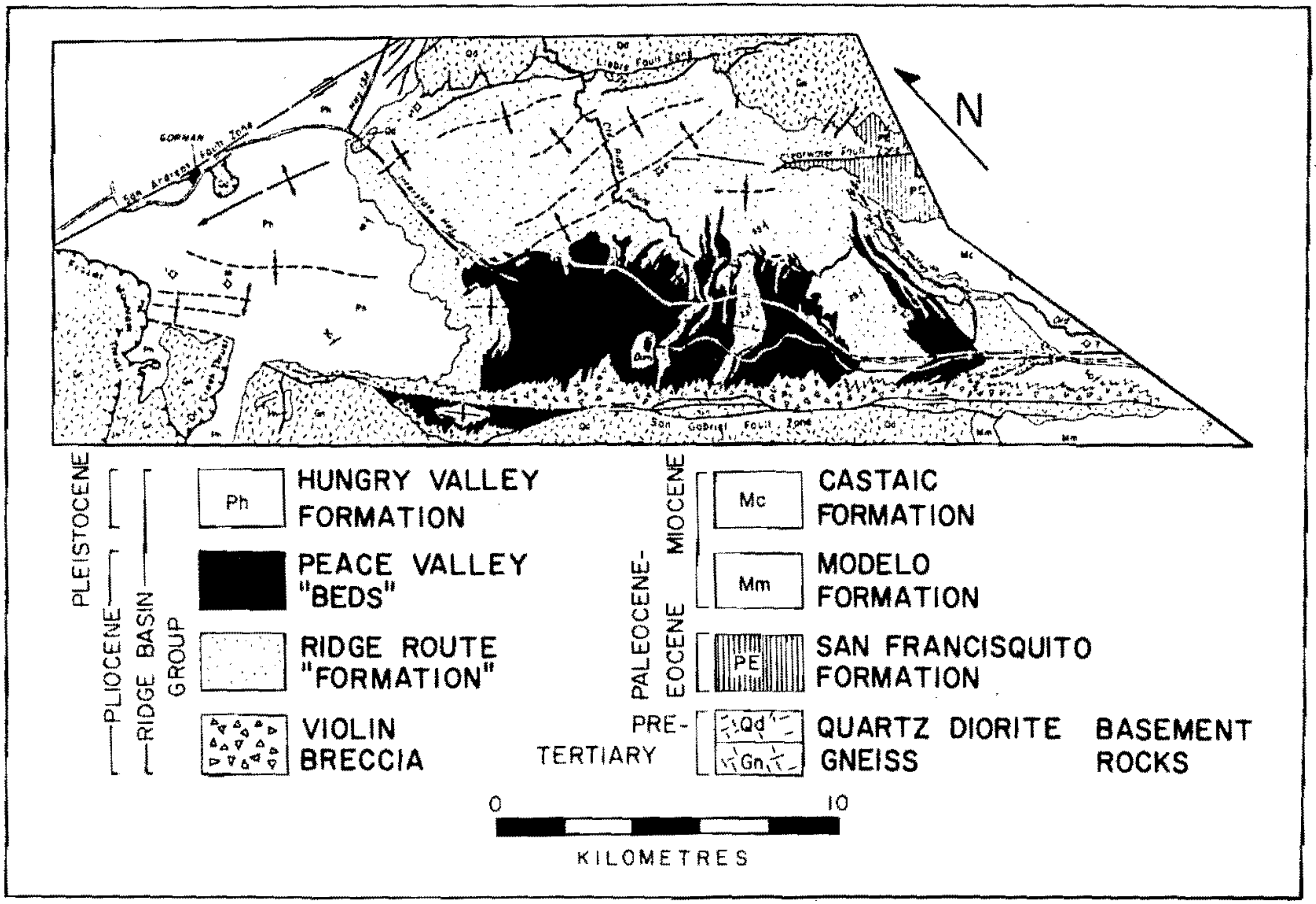
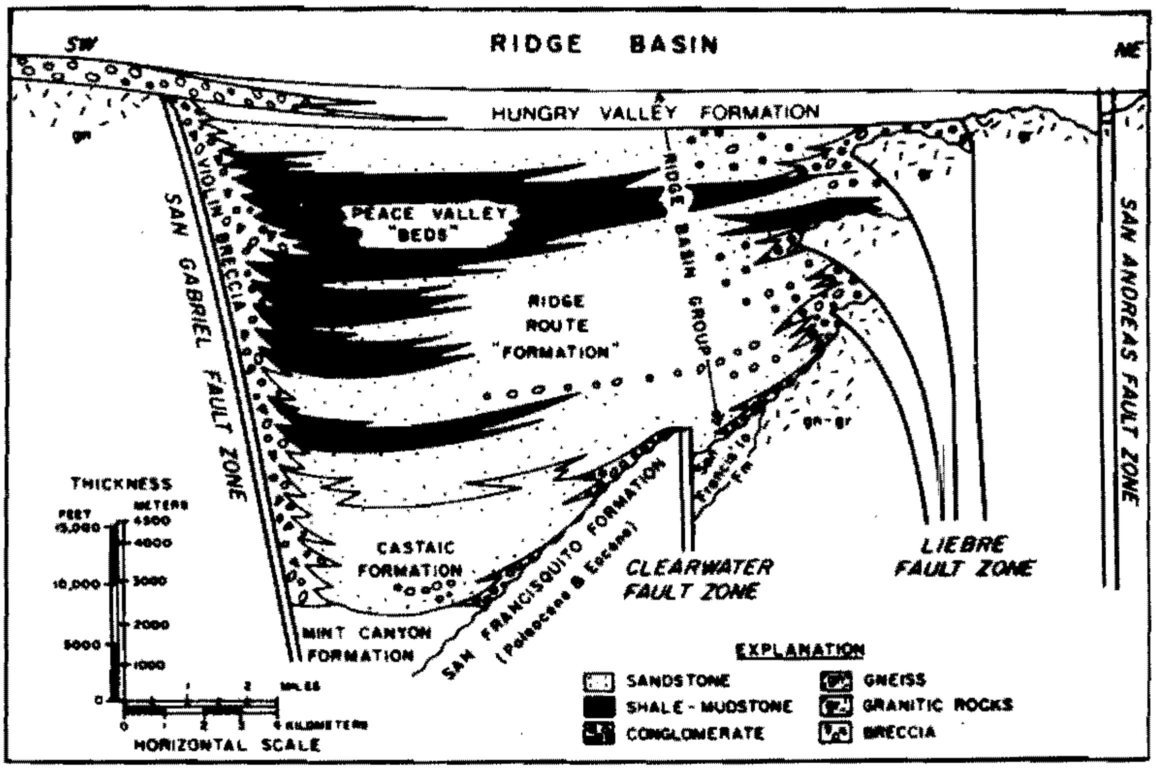

N
GORMAN
San Andreas Fault Zone
Liebre Fault Zone
San Gabriel Fault Zone
PLEISTOCENE
PLIOCENE
RIDGE BASIN GROUP
Ph HUNGRY VALLEY FORMATION
PEACE VALLEY "BEDS"
RIDGE ROUTE "FORMATION"
VIOLIN BRECCIA
MIOCENE
Mc CASTAIC FORMATION
Mm MODELO FORMATION
PALEOCENE-EOCENE
PE SAN FRANCISQUITO FORMATION
PRE-TERTIARY
Qd QUARTZ DIORITE
Gn GNEISS
BASEMENT ROCKS
0
10
KILOMETRES

Fig. 6. Diagrammatic geologic cross-section depicting major stratigraphic relationships in the Ridge Basin (modified from Link and Osborne 1978).



RIDGE BASIN
SW
NE
HUNGRY VALLEY FORMATION
PEACE VALLEY "BEDS"
RIDGE ROUTE "FORMATION"
RIDGE BASIN GROUP
VIOLIN BRECCIA
SAN GABRIEL FAULT ZONE
SAN ANDREAS FAULT ZONE
CASTAIC FORMATION
MINT CANYON FORMATION
SAN FRANCISQUITO FORMATION (Paleocene & Eocene)
CLEARWATER FAULT ZONE
LIEBRE FAULT ZONE
gn-gr
THICKNESS
FEET
METERS
15,000
10,000
5000
0
4500
4000
3000
2000
1000
MILES
KILOMETERS
HORIZONTAL SCALE
EXPLANATION
SANDSTONE
SHALE - MUDSTONE
CONGLOMERATE
GNEISS
GRANITIC ROCKS
BRECCIA

PREVIOUS WORK

Stratigraphy.--Clements (1937, p. 218) briefly described continental strata within the northern part of the Ridge Basin that he called the "Ridge Route Formation." The top of his formation was not defined, and he did not give a type section; but he tentatively assigned a Pliocene age to the strata on the basis of stratigraphic position.

Eaton (1939) published a general geologic sketch map of the Ridge Basin, and subdivided the strata into four units that he called "divisions": First Division (Lower Pliocene?), Second Division (Middle Pliocene?), Third Division (Upper Pliocene?), and Fourth Division (Lower Pleistocene?). Eaton (p. 548) rejected Clements' (1937) "Ridge Route Formation" because three of Eaton's divisions obliquely transected the lower contact of the "Ridge Route Formation" and because the top of the "formation" was not defined.

David (1945) identified a middle Miocene to Pliocene fish from about the stratigraphic middle of the Ridge Basin. The locality she gave falls on Clements' (1937) map within the Modelo Formation, although she refers to strata at this location as the "Ridge Formation" [sic]. This locality is within the "Second Division" of Eaton (1939) and is in strata now called the Peace Valley "beds." Based on the paleoflora, Axelrod (1950) proposed a middle Pliocene age for beds in approximately the stratigraphic middle of the Ridge Basin; these strata are now called the Peace Valley "beds." He also (p. 168) named the Ridge Basin Broup to include all four of Eaton's "divisions."

Crowell (1950) mapped the upper part of the Ridge Basin strata in the Hungry Valley area. He (p. 1633) named and described the Hungry Valley Formation and assigned to this sequence of sandstones a late-middle to early-late Pliocene age based on two horse teeth (p. 1638). He also described another finer-grained sequence of strata and informally called them the Peace Valley "beds"; he said (p. 1631) that he did not give these finer-grained beds a formation name because the base of the sequence was not exposed within the area studied. Crowell did not use Clements' (1937) "Ridge Route Formation" because he said (p. 1628) that there was not a type sectión nor was the entire area mapped. He suggested, however, that "future work may make it desirable to elevate Clements' formational name to group status." Eaton's (1939) "Third Division" generally corresponds to Crowell's Peace Valley "beds" and Eaton's "Fourth division," in general, corresponds to Crowell's Hungry Valley Formation, although the lithologic contacts are oblique to each other (Crowell 1950, p. 1628).

Dehlinger (1952) described strata of the lower portion of the sequence in the Ridge Basin. These strata are now in the lower Ridge Basin Group and Castaic Formation. He adopted Clements' (1937) terminology, but omitted reference to the previous works of David (1945), Axelrod (1950), and Crowell (1950).

Crowell (1954) produced a map of the Ridge Basin Group and surrounding rocks. He formally named the Violin Breccia and divided the Ridge Basin Group into the Hungry Valley Formation and the Violin Breccia with the remainder of the Group referred to as "Ridge Basin Group undifferentiated." He (1973) briefly discussed the facies changes between the Violin Breccia and other sandstone and shale units in this undifferentiated part of the Group. He later (1975) revised part of his former map and produced several diagrammatic cross sections of the Ridge Basin.

Irvine (1977) studied a shale unit of the Peace Valley "beds," and determined that this was lake sediment with irregular cycles; this sediment was interpreted to be of fresh to brackish water origin with alkaline conditions.

Link and Osborne (1978) identified and discussed eleven facies in the Ridge Basin Group and described a new unit in this group, the Ridge Route "formation." Link et al. (1978) studied biosedimentary structures and paleoenvironments in the Ridge Basin Group and identified, in a formal manner, the Peace Valley Formation and Ridge Route Formation on their geologic map and cross section (p. 144-145).

Ensley and Verosub (1979) produced a preliminary magnetic time scale that indicates the lower portion of the Ridge Basin Group to have existed during the middle Gilbert (approximately 3.9 million years ago) or Gauss Epoch (2.3-3.3 million years ago) of the early Pliocene.

Herein, the more informal usage (Link and Osborne 1978) of Peace Valley "beds" and Ridge Route "formation" is followed because I am not convinced of the formality of these units. That is, the Ridge Route "formation" of Link and Osborne (1978) is not Clements' (1937) unit of the same name within the same structural basin.

Paleontology.--David (1945) first published on Ridge Basin Group fossils. She identified a stickleback fish of middle Miocene to, more likely, Pliocene age from Lacustrine sediment near the stratigraphic center of the basin. Axelrod (1950) investigated the paleoflora and concluded that the Pliocene climate was similar to that presently at Baja, California. Crowell (1950) found molluscs in the Hungry Valley Formation that were identified as Anodonta cf. A. cygnea and ?Lymnaea sp. He also found camel, mastodon, turtle remains, and horse teeth. Miller and Downs (1974) described various vertebrates, including Pliohippus, a camel, an antelope, and a large cat from the Hungry Valley Formation. Link et al. (1978) studied lacustrine biosedimentary structures from the Ridge Route "formation" and found oncolites, ooids, and ostracods associated with stromatolites. Squires (1979) identified two species of dragonfly nymphs from the Hungry Valley Formation and interpreted them as shoreline-dwelling.

Other fossils from the Ridge Route "formation" and Peace Valley "beds" include several Cyprinodontidae, fresh- to brackish-water fish, found by Martin Link and identified by Bruce Welton of the Los Angeles County Museum of Natural History. Link also found a sloth tooth in the Ridge Route "formation" that was identified as Thinobadistes (Webb 1979). Harper (1980) found a rabbit tibia that was identified by Bruce Welton as a Pliocene (late Miocene to late Pliocene) Hypolagus sp. He (1979) also found a fish bone identified by Welton as Gasterosteus sp. and fish scales representing either Atherinidae or Cyprinodontidae; both families contain freshwater to brackish water species.

METHODS

Field methods.--Molluscs were located along the Old Ridge Route by visual inspection and removed by pick and shovel along weathered zones. Field work was done in July through December, 1978. The sections were measured with a metric Jacob's staff and Brunton compass from at least 10 m above and to 10 m below the fossil horizons where possible. Fossils were collected within the measured sections. Although most of the matrix was removed from the fossils at the outcrop, enough was left to protect the samples during transport. Each locality was collected for one hour or more, and an attempt was made to collect the best possible specimens of each species. Each sample was labeled immediately after collecting from a locality. Field numbers were assigned to each horizon of fossils at each locality (Appendix C). Los Angeles County Museum of Natural History-Invertebrate Paleontology (LACMNH) locality numbers were later assigned to each collecting locality. Bulk samples of ostracodes were sent to Dr. Richard Forester, United States Geological Survey, Denver, for preparation, identification, and paleoenvironmental interpretation. Vertebrate remains were given to Dr. Bruce Welton, of the Los Angeles County Museum of Natural History, for identification.

Lithologic descriptions were made with a 10X hand lens at the outcrop using the classification of Dott (1964). That classification divides fine- and medium-grained clastics into arenite (less than 15% silt and clay), wacke (greater than 15% and less than 75% silt and clay), or mudstone (greater than 75% silt and clay). Mudstone was further subdivided into siltstone or claystone in the field by estimating the texture. Wacke and arenite were further subdivided into arkose (greater than 50% feldspar) and quartzose (greater than 75% quartz) or lithic sandstone (greater than 50% rock fragments). The overall sorting was estimated from the visual chart of Compton (1962, p. 214), and grain roundness was determined from the medium size (Wentworth scale) of quartz grains using the roundness scale of Powers (1953). Sphericity was determined using the visual chart of Folk (1974, p. 9) with the medium grain size of quartz. Rock colors were estimated from a standardized rock color chart (Goddard et al. 1963) using fresh, dry surfaces.

Relative abundance of fossils was arbitrarily set so that rare meant 0 to 3 individuals per metre along strike; uncommon, 3 to 10 individuals; common, 10 to 20 individuals; and abundant, more than 20 individuals (Appendix B).

Laboratory methods.--Laboratory methods included preparation, labeling, statistics, and photography. Most of the preparation was completed at the LACMNH. Specimens were unpacked and numbered with India ink. The matrix was removed using a carbide scribe in a pin vice following the methods of Grenda (1977, p. 14), as well as by ultrasonic vibration, dilute acidic acid etching, and wet sieving of bulk samples.

Prepared specimens were separated into species and then measured for length, width and height. The measurements were analyzed statistically with SAS (Statistical Analysis System) (Barr et al. 1976), a computer program to characterize each species and aid in species identification. Each species was then identified from published literature.

All fossils in Plate 1 were photographed with a Nikkormat 35 mm camera body, a Nikon PB4 bellows mounted on a Nikon copy stand, and a Nikkor 105 mm macro lens. Specimens were coated with a sublimate of ammonium chloride and set in modeling clay for support. Lighting consisted of a hand-held Vivitar 283 electronic flash with a varipower (rheostat) as the main source in the upper left and a white index card as a fill reflector in the lower right. The aperture was f/32, and magnification was 0.8X for figures 1-16 and 1.6X for the remaining figures. Kodak Panatomic-x film was used and developed in Rodinal with a dilution of 1:100, at 20°C. Prints were made on Kodak Kodabromide paper (single weight, F-2). Photography of the plate was done with a 8 X 10 inch Calumet view camera using Plux X film and printed on Kodak Kodabromide (single weight, F-3).

STRATIGRAPHY

General.--The Ridge Basin Group consists of the Violin Breccia, Peace Valley "beds," Ridge Route "formation," and the Hungry Valley Formation (Figure 6) with an overall thickness of about 9000 m (Link and Osborne 1978). The Violin Breccia is a depositional breccia found only along the western edge of the basin, and the Hungry Valley Formation is stratigraphically the uppermost unit of the Ridge Basin Group. The Ridge Route "formation" and Peace Valley "beds" are intertonguing lithofacies. The Ridge Route "formation," mainly to the east, represents mostly fluvial and alluvial fan facies consisting of sandstone and conglomerate with lesser amounts of nearshore and offshore facies consisting of finer sediment. The Peace Valley "beds," mainly to the west, represent predominantly mid-basin lacustrine and marine mudstones.

More than half of the thickness of the Ridge Route "formation" and about one fifth of the thickness of the Peace Valley "beds" was examined for molluscs in the lower part of the Ridge Basin Group. Over 600 m of sections were measured along the northeastern side of the basin within the Ridge Route "formation" and Peace Valley "beds" (Figures 7 to 12). Sections with molluscs in the sandstone and mudstone unit informally referred to as the "Fisher Springs sandstone member of Ridge Route formation" were measured by Harper (1978-1980). Refer to Plate 2 for specific locations.

Measured sections 15 and 16 (Figure 11) probably correlate stratigraphically and depositionally. The base of the two sections

Fig. 7. Measured section 1 and explanation for Figures 7 to 12 (format after Selley 1970 and Harper 1980). Accession numbers are LACMNH locality numbers. Refer to Appendix A for lithologic descriptions and Plate 2 for locations of sections. Plants include stem and leaf impressions, wood fragments, and charophytes.

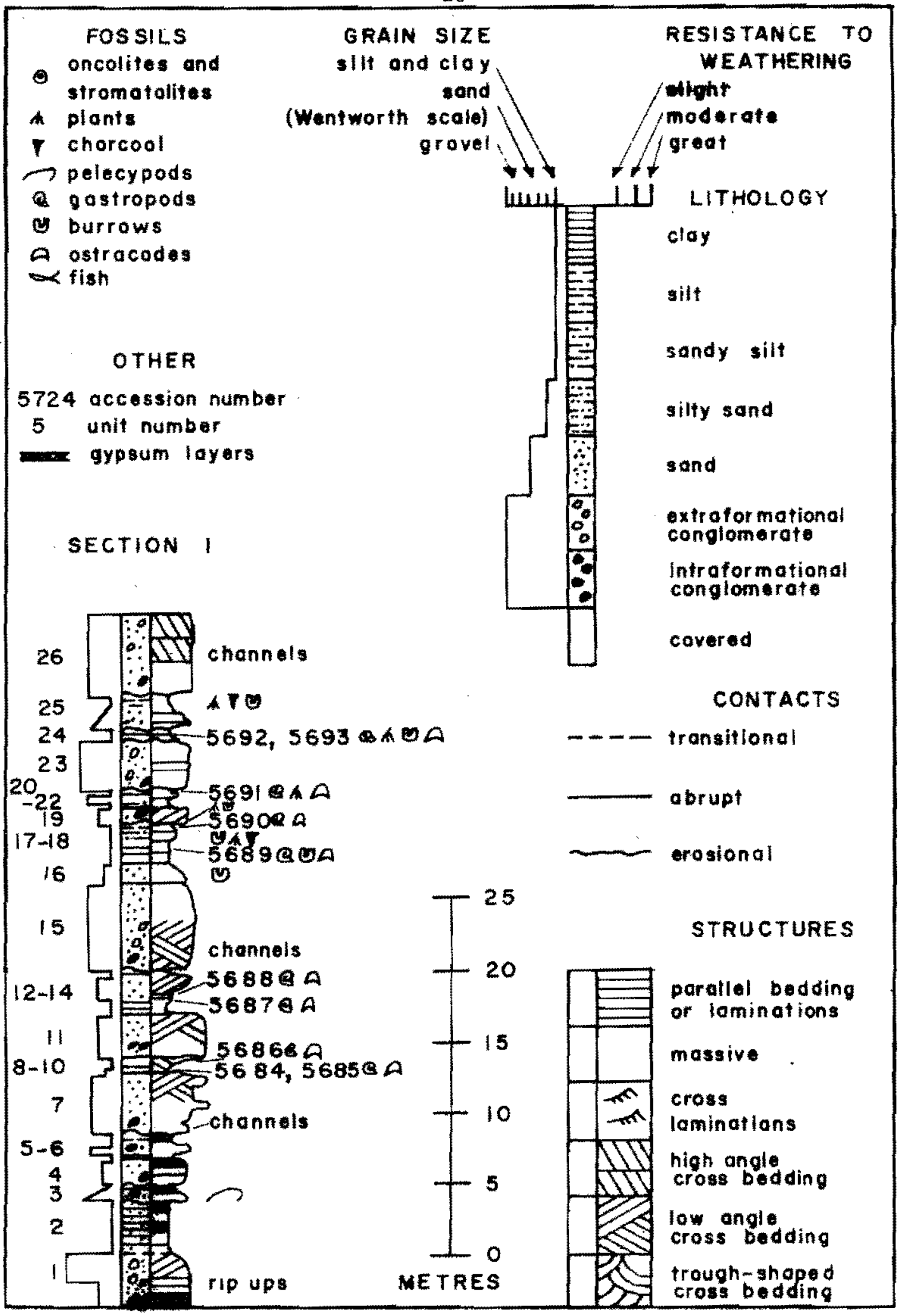

FOSSILS
oncolites and stromatolites
plants
charcoal
pelecypods
gastropods
burrows
ostracodes
fish
GRAIN SIZE
silt and clay
sand
(Wentworth scale)
gravel
RESISTANCE TO WEATHERING
slight
moderate
great
LITHOLOGY
clay
silt
sandy silt
silty sand
sand
extraformational conglomerate
intraformational conglomerate
covered
OTHER
5724 accession number
5 unit number
gypsum layers
SECTION I
26
25
24
23
20-22
19
17-18
16
15
12-14
11
8-10
7
5-6
4
3
2
1
channels
5692, 5693
5691
5690
5689
channels
5688
5687
5686
5684, 5685
channels
rip ups
25
20
15
10
5
0
METRES
CONTACTS
transitional
abrupt
erosional
STRUCTURES
parallel bedding or laminations
massive
cross laminations
high angle cross bedding
low angle cross bedding
trough-shaped cross bedding

Fig. 8. Measured sections 2 to 6. Explanations are given in Figure 7. Refer to Appendix A for lithologic descriptions and Plate 2 for location of sections.

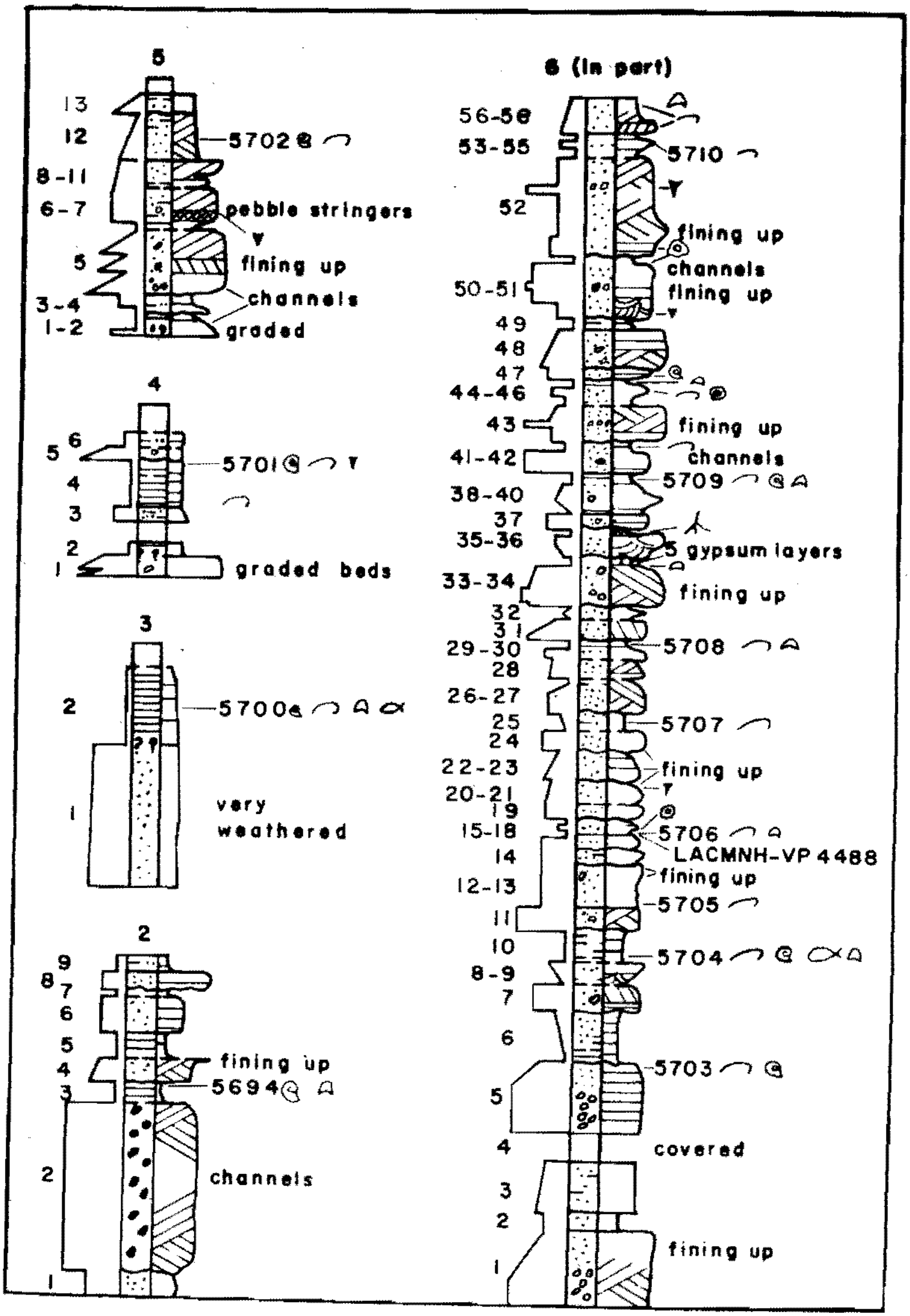

5
13
12
5702
8-11
6-7
pebble stringers
5
fining up
3-4
channels
1-2
graded
4
6
5
5701
4
3
2
1
graded beds
3
2
5700
1
very
weathered
2
9
8
7
6
5
fining up
4
3
5694
2
channels
1
6 (in part)
56-58
53-55
5710
52
fining up
channels
50-51
fining up
49
48
47
44-46
43
fining up
41-42
channels
38-40
5709
37
35-36
5 gypsum layers
33-34
fining up
32
31
29-30
5708
28
26-27
25
5707
24
22-23
fining up
20-21
19
15-18
5706
LACMNH-VP 4488
14
12-13
fining up
5705
11
10
5704
8-9
7
6
5703
5
4
covered
3
2
fining up
1

Fig. 9. Measured sections 6 to 10. Explanations are given in Figure 7. Refer to Appendix A for lithologic descriptions and Plate 2 for location of sections.

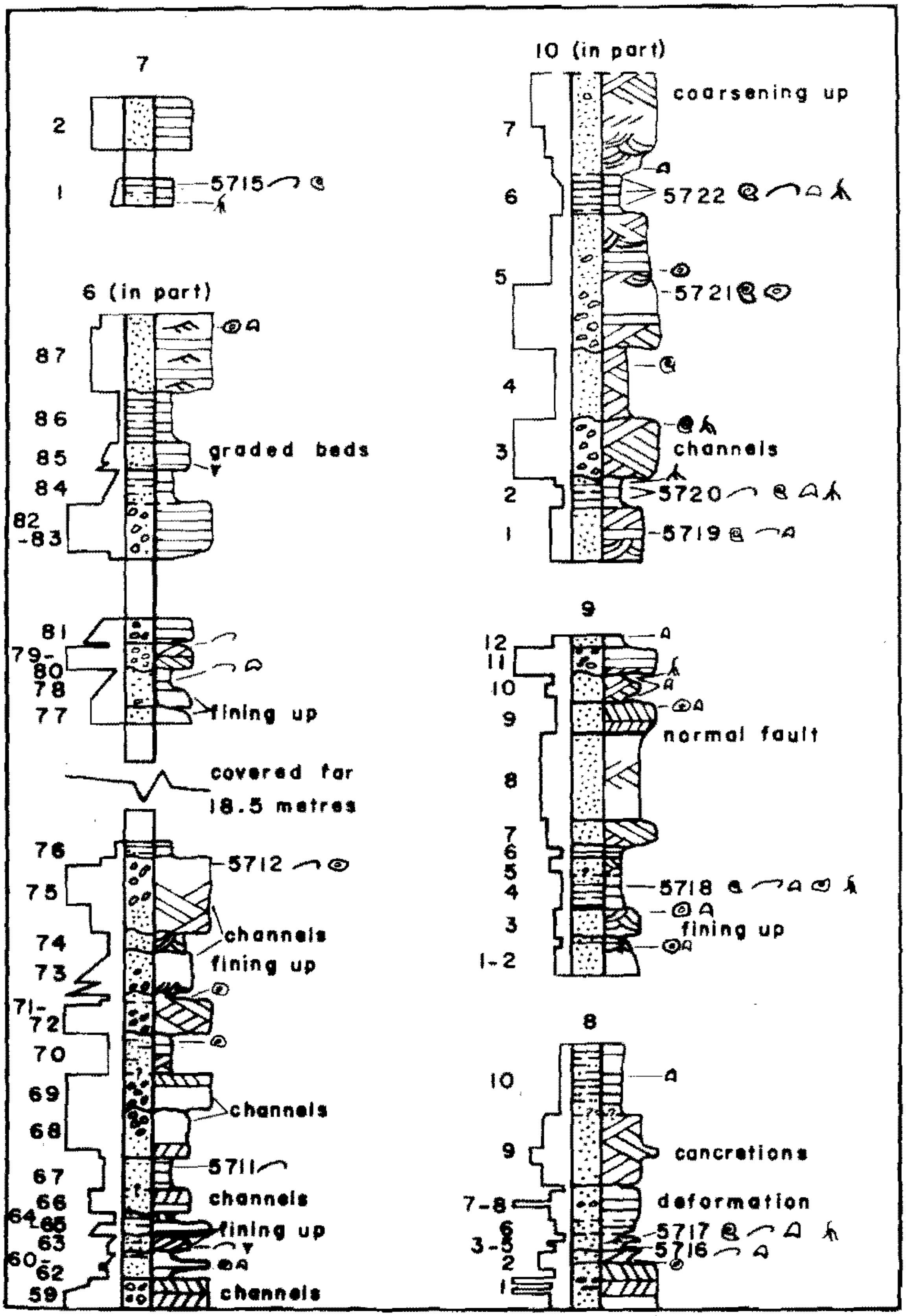

7
2
1
5715
6 (in part)
87
86
85
graded beds
84
82
-83
81
79-
80
78
77
fining up
covered for
18.5 metres
76
5712
75
channels
74
fining up
73
71-
72
70
69
channels
68
5711
67
66
channels
64
65
63
fining up
60-
62
59
channels
10 (in part)
coarsening up
7
6
5722
5
5721
4
3
channels
2
5720
1
5719
9
12
11
10
9
normal fault
8
7
6
5
4
5718
3
fining up
1-2
8
10
9
concretions
7-8
deformation
6
5717
3-5
5716
2
1

Fig. 10. Measured sections 10 to 14. Explanations are given in Figure 7. Refer to Appendix A for lithologic descriptions and Plate 2 for location of sections.

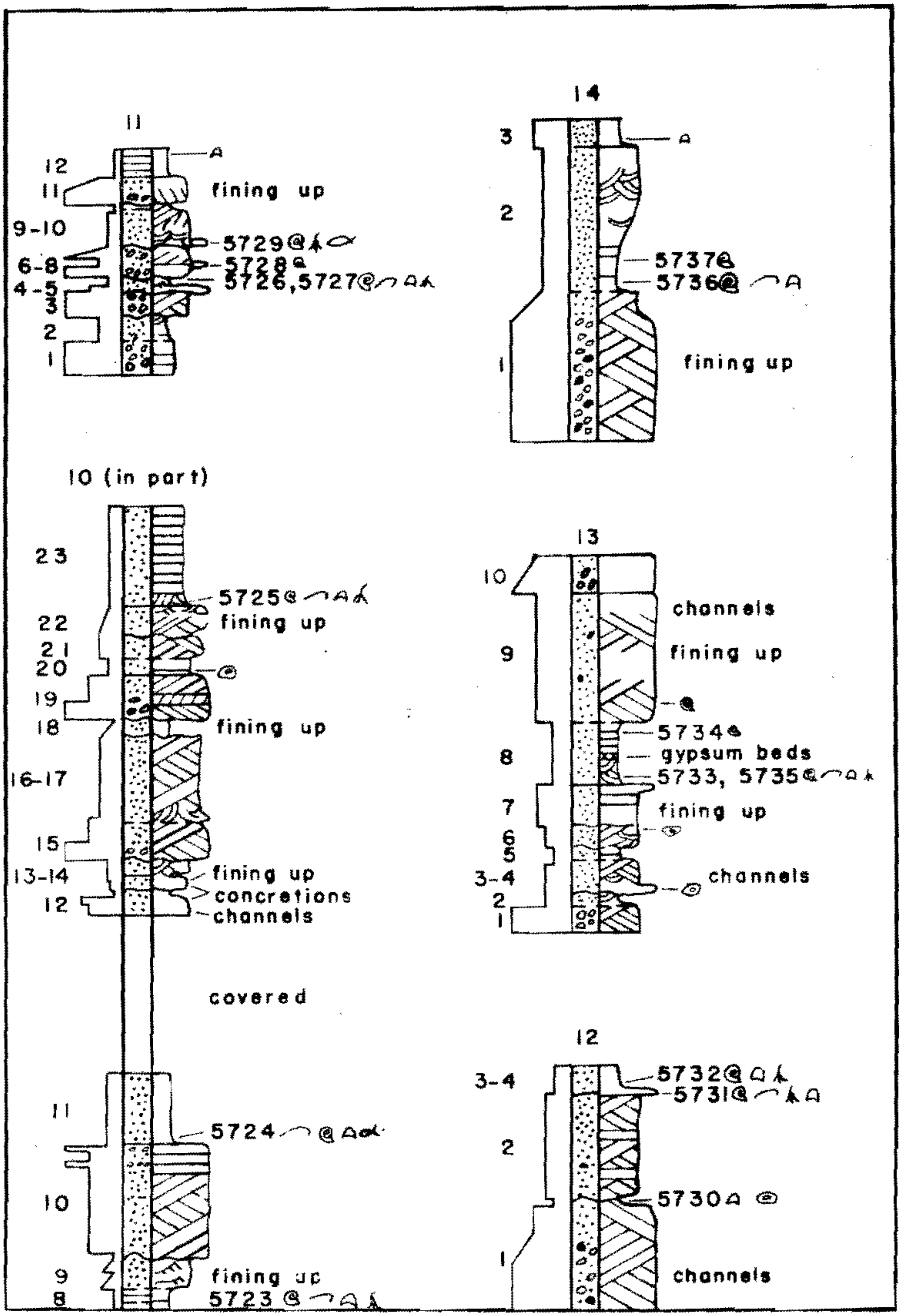

11
12
11
9-10
6-8
4-5
3
2
1
A
fining up
5729
5728
5726, 5727
14
3
2
1
A
5737
5736
fining up
10 (in part)
23
22
21
20
19
18
16-17
15
13-14
12
5725
fining up
fining up
fining up
concretions
channels
covered
11
10
9
8
5724
fining up
5723
13
10
9
8
7
6
5
3-4
2
1
channels
fining up
5734
gypsum beds
5733, 5735
fining up
channels
12
3-4
2
1
5732
5731
5730
channels

Fig. 11. Measured sections 15 to 18. Explanations are given in Figure 7. Refer to Appendix A for lithologic descriptions and Plate 2 for location of sections.

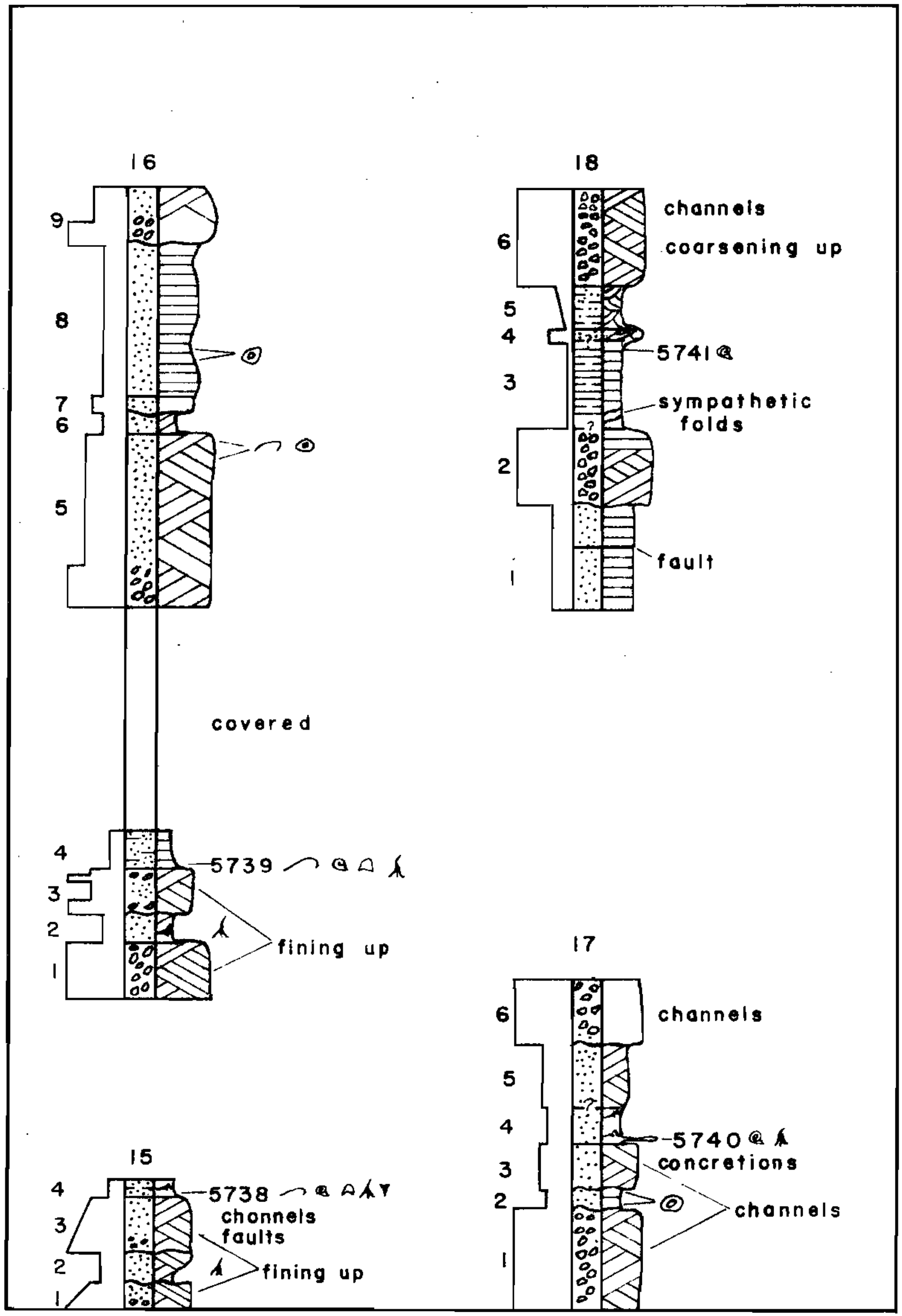
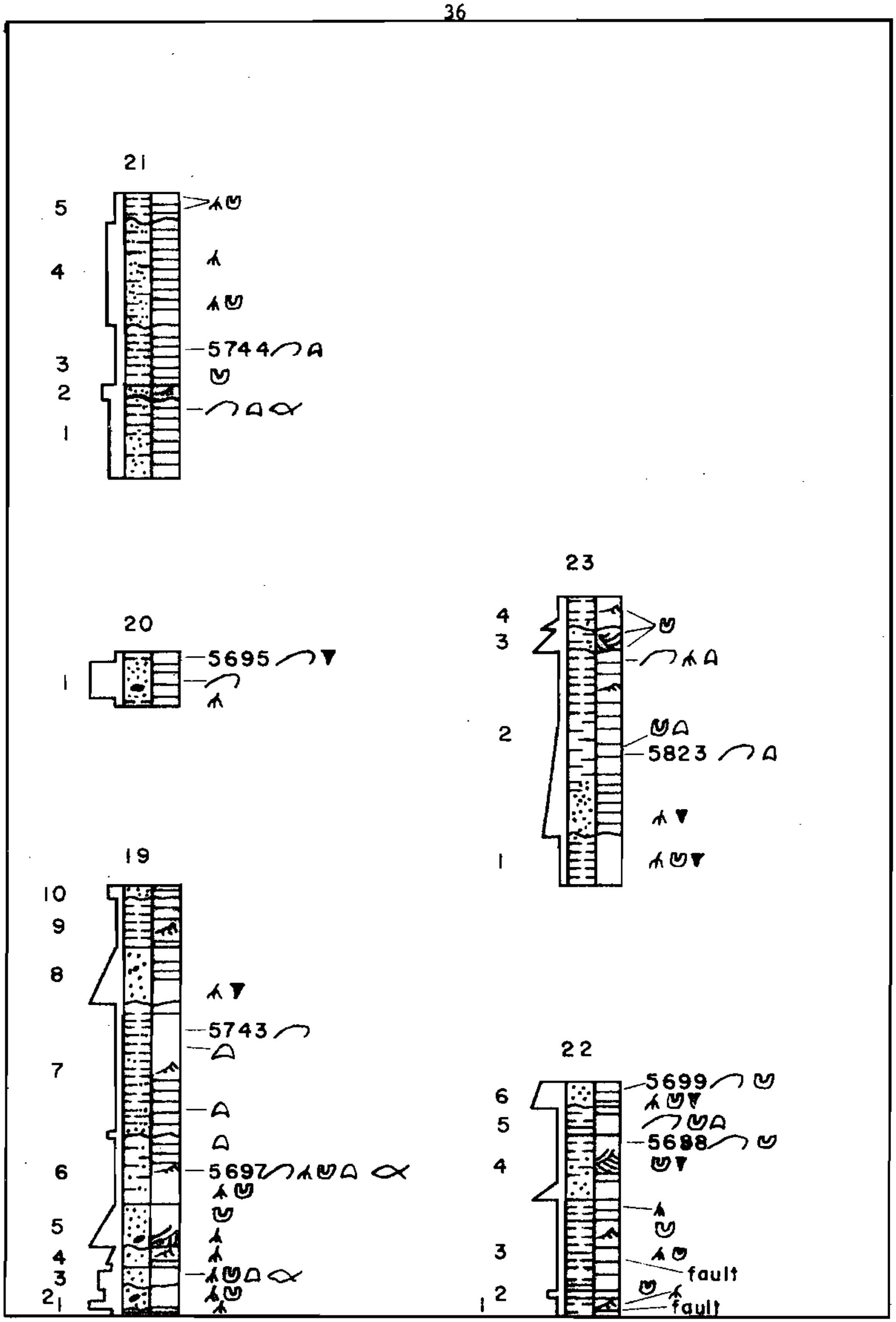

16
9
8
7
6
5
covered
4
3
2
1
5739
fining up
18
channels
coarsening up
6
5
4
3
2
1
5741
sympathetic folds
fault
15
4
3
2
1
5738
channels
faults
fining up
17
6
5
4
3
2
1
channels
5740
concretions
channels

Fig. 12. Measured sections 19-23. Lithologic information and sections are from Harper (1979). Interpretations and drafting are mine. Explanations are given in Figure 7. Refer to Appendix A for lithologic descriptions and Plate 2 for location of sections.


21
5
4
3
2
1
5744
20
1
5695
23
4
3
2
1
5823
19
10
9
8
7
6
5
4
3
2
1
5743
5697
22
6
5
4
3
2
1
5699
5688
fault
fault

are about 200 m apart and are on opposite limbs of a syncline with the axis between the sections. The first four units of both sections have similar thicknesses, rock colors, sedimentological structures, and lithological sequences. Plant remains are abundant in unit two of both sections and the molluscan faunas and abundances are identical in unit four of both sections.

Measured sections 1 and 15 are progressively higher stratigraphically. Measured sections 17 and 18 could not be correlated stratigraphically due to folding and faulting. Measured sections 19 to 23 are within the unit informally referred to as the "Fisher Springs sandstone member" (Harper 1978-1980) and are stratigraphically between measured sections 2 and 3.

Lithology.--The general lithology of the Ridge Basin Group is sandstone, pebbly sandstone, and interbedded mudstone. The Ridge Route "formation" consists mainly of sandstone, pebbly sandstone, and conglomerate that coarsen towards the east. The Peace Valley "beds" consist of mudstone, shale, and interbedded, silty, fine-grained sandstone. The uppermost Peace Valley "beds" also contain analcine, pyrite, dolomite, and gypsum nodules (Irvine 1977).

The strata of section 1 are mainly siltstone and wacke with interbedded gypsum and conglomeratic sandstone. The remainder of the sections along the Old Ridge Route are predominantly arkosic wacke with lesser amounts of interbedded arkosic arenite, siltstone, conglomerate, and claystone (refer to Appendix A for detailed descriptions). Fining upward sequences are common.

Sedimentary structures.--A wide variety of primary and secondary structures are present in the Ridge Route "formation." Dish structures have been described from beds stratigraphically below measured section 1 (Nilsen et al. 1977) and flute casts were observed in section 1. Other sedimentary structures observed include tabular and trough-shaped ripples that are grouped or solitary, climbing ripples, grouped and solitary tabular dunes, grouped and solitary trough-shaped dunes (large- and very large-scale), tabular slipfaces, large- and small-scale parallel laminations (upper and lower flow regime), channels from very large-scale to small-scale, partial Bouma sequences, graded beds, rip up clasts, slump folding, soft sediment deformation, and burrows.

ANALYSIS OF FAUNA

Composition.--The distribution and relative abundance of taxa found in the Ridge Basin Group is shown in Appendix B.

The nonmarine molluscs of the Ridge Basin Group are now known to include ten species, distributed in nine genera and five families:

Unionidae
- *Anodonta oregonensis* Lea

Sphaeriidae
- *Musculium lacustre* (Müller)
- *M. transversum* (Say)
- *Pisidium* cf. *P.* (*Cyclocalyx*) *nitidum* Jenyns

Hydrobiidae
- *Fontelicella* aff. *F.* (*F.*) *truckeensis* Yen
- *Tryonia* aff. *T. protea* Gould
- Species 1
- Species 2

Lymnaeidae
- ?*Stagnicola* sp.

Planorbidae
- ?*Planorbula* aff. *P. armigera* (Say)

One other molluscan species, *Chlamys* (*Chlamys*) cf. *C.* (*C.*) *hodgei*, collected by Martin Link, is also known from the late Miocene marine Castaic Formation (Wilson 1978). Other fossils include nine species of ostracodes, plant fragments, charcoal, wood, charophytes, stromatolites, fish remains, and seven vertebrates.

Preservation.--Plants are preserved as impressions (most common), charcoal fragments, or wood. Charophytes, ostracodes, and mollusc shells generally are well preserved. Internal and external molds of molluscs are well preserved in siltstone and fine-grained wackes but poorly preserved in coarser sediments and arenites. Fish are preserved as disarticulated impressions, scales, or bones.

Taphonomy.--About half of the molluscan individuals appear to have been transported. Half of these were found as concentrations of molluscs associated with ostracodes. Rarely were molluscs deformed or crushed by overlying sediment. Scattered localities contained transported and abraded molluscan fragments and ostracodes only, whereas most localities with transported molluscs yielded well preserved specimens. Burial after death must have been varied since some localities contain well-preserved transported molluscs whereas others are more abraded. The nacreous layer of Anodonta is often partially preserved, even in some transported specimens.

Occurrence.--Molluscs occur in claystone, siltstone, sandstone, and conglomerate. Siltstone, very fine-grained wacke, and claystone contain the majority of the molluscan fossils. Most nontransported molluscs occur in siltstone to fine-grained wacke; transported molluscs usually occur in fine- to medium-grained arenite and wacke.

All of the hydrobiids occur stratigraphically in the lower portion of the Ridge Route "formation" and Peace Valley "beds." The other nonmarine molluscs occur in the Ridge Route "formation" and Peace Valley "beds" above the hydrobiids except in measured section 3, where Fontelicella aff. F. (F.) truckeensis and Hydrobiidae species 2 are associated with Musculium lacustre, M. transversum, and ?Planorbula aff. P. armigera.

Molluscs that are stratigraphically or nearly stratigraphically equivalent to fossils in the lower part of the Ridge Route "formation" were not found in the mudstone to the southwest in the marine or lacustrine facies of the lower Peace Valley "beds." ?Stagnicola and ?Planorbula aff. P. armigera appear farther north (measured sections 17 and 18) along the Old Ridge Route in the Ridge Route "formation" than the unionid and sphaeriids. This sediment could not be correlated stratigraphically with measured section 15 (refer to Plate 2 for location).

Age of fauna.--Ridge Basin nonmarine molluscs do not suggest an age for the basin. All of the nonmarine molluscs are represented in modern environments. *Chlamys* (*Chlamys*) cf. *C*. (*C*.) *hodgei*, from the lowermost portion of the Ridge Route "formation," has been reported from late Miocene marine deposits (Wilson 1978). The ostracodes probably indicate a late Miocene age for the Ridge Route "formation" and Peace Valley "beds" (Forester 1980).

Vertebrate remains suggest a late Pliocene age for the lower Hungry Valley Formation (Crowell 1950); a late Pliocene to Miocene age for the Hungry Valley Formation (Miller and Downs 1974); and a Pliocene to middle Miocene age for the middle of the Ridge Basin Group (David 1945). A Pliocene age has also been inferred for the middle of the Ridge Basin Group based on the paleoflora (Axelrod 1950). Recently, Ensley and Verosub (1979) have suggested an early Pliocene age for the lower portion of the Ridge Basin Group based on magnetostratigraphy.

MOLLUSCAN PALEOECOLOGY

Freshwater environments are indicated by the presence of *Anodonta*, *Musculium*, *Pisidium*, *Fontelicella*, *Stagnicola*, and *Planorbula*. *Anodonta oregonensis* has been reported only from lakes, ponds, and rivers (Hemphill 1891). *Musculium lacustre* usually occurs in ponds and small lakes but may be found in large lakes, creeks, and rivers (Burch 1975a). *Musculium transversum* generally occurs in large lakes, rivers, and sloughs (summarized from other workers by Burch 1975a, p. 35) and seldom inhabits ponds (Gale 1977, p. 12). *Pisidium* (*Cyclocalyx*) *nitidum* inhabits lakes, ponds, creeks, and rivers (Clarke 1973, p. 91). *Fontelicella* (*Fontelicella*) *truckeensis* has been reported living in small streams or springs (Gregg and Taylor 1965, p. 107).

Stagnant water is primarily indicated by the presence of *Stagnicola* and *Planorbula*. *Stagnicola* has been reported from lakes, ponds, streams, and pools. A few species prefer stagnant water (Baker 1928, p. 210). *Planorbula* is characteristic of ponds and marshes (Taylor 1966b, p. 90).

Brackish water may be indicated by the presence of *Tryonia* or hydrobiids. *Tryonia protea* has been reported from freshwater and brackish springs and spring outflows (Keep 1911, p. 315) as well as from Pleistocene Lake Bonneville (Roscoe 1961, p. 26). *Tryonia* aff. *T. protea* is interpreted to withstand a wide salinity range because, in the lower Ridge Route "formation," it is commonly associated with

Cyprideis aff. C. beaconensis, an ecophenotypic ostracode (Forester 1979). According to Forester (1980), C. aff. C. beaconensis populations with smooth valves represent higher salinities than populations with most or all noded valves. Tryonia aff. T. protea is found with populations of smooth tested Cyprideis aff. C. beaconensis and with populations containing some noded valves. Hydrobiids usually occur in freshwater although some inhabit brackish water (Taylor 1966a, p. 169).

Shallow freshwater is suggested by the presence of ?Planorbula aff. P. armigera and Pisidium (Cyclocalyx) nitidum. Planorbula armigera is seldom found in water depths greater than 1 m (La Rocque 1966-1970, p. 507). Pisidium (C.) nitidum is reported to live in water depths less than 3.7 m (Baker 1928).

Nonmarine molluscs are found in association with fish, ostracodes, charcoal, plants, charophytes, stromatolites, and oncolites. Ostracodes are often more abundant than molluscs and also appear in strata where molluscs are absent. Musculium lacustre is usually found with M. transversum, and may suggest that aquatic vegetation was present (Clarke 1973).

In the Ridge Basin, the occurrence of ?Planorbula aff. P. armigera and ?Stagnicola with or without Anodonta oregonensis (Figures 13 and 14) is assumed to represent shallow water ponds or marshes on a floodplain. These associations commonly occur in the fluvial deposits along the northeastern margin of the Ridge Basin (Figure 15). In general, molluscs in the Ridge Route "formation" and Peace Valley "beds" associated with abundant in situ nonmarine ostracodes probably represent water depths of less than about 7 m (Forester 1979). Anodonta oregonensis, in association with stromatolites, is assumed to represent shallow freshwater (Figure 16).

Fig. 13. Photograph of fossil assemblage of Anodonta oregonensis, ?Stagnicola, charcoal, and wood fragments from LACMNH locality 5738. Note break ridges on juvenile A. oregonensis (left center). Magnification X1. Matrix consists of up to 25% ostracode remains. The general lithology is siltstone interbedded with very fine-grained wacke.

Fig. 14. Photograph of fossil assemblage of Anodonta oregonensis, ?Planorbula aff. P. armigera, charcoal fragments, and plant fragments from LACMNH locality 5738. Ostracodes are less than 1% of total matrix. Magnification X1. The general lithology is siltstone interbedded with very fine-grained wacke.

Fig. 15. Inferred shallow water paleoenvironments in the Ridge Basin (Link and Osborne 1978, p. 186).

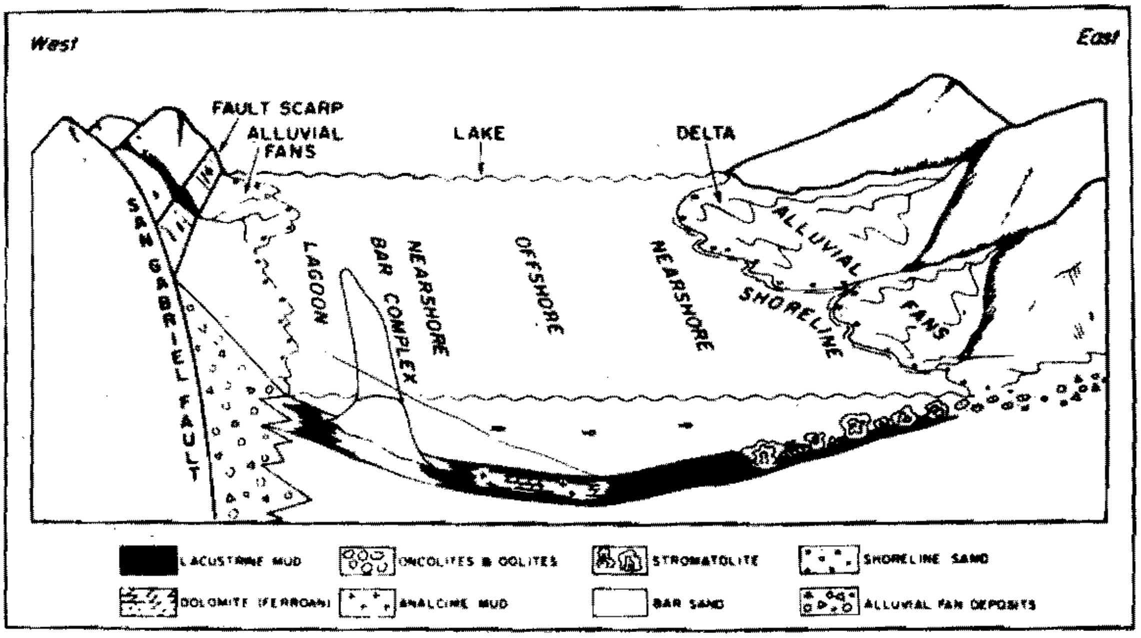

West
East
FAULT SCARP
ALLUVIAL FANS
LAKE
DELTA
SAN GABRIEL FAULT
LAGOON
NEARSHORE BAR COMPLEX
OFFSHORE
NEARSHORE
ALLUVIAL FANS
SHORELINE
LACUSTRINE MUD
ONCOLITES & OOLITES
STROMATOLITE
SHORELINE SAND
DOLOMITE (FERROAN)
ANALCIME MUD
BAR SAND
ALLUVIAL FAN DEPOSITS

Fig. 16. Photograph of polished section of pelecypod fragments encrusted by stromatolitic algae at LACMNH locality 5712. Magnification approximately X1.

ENVIRONMENTS OF DEPOSITION

Synthesis of environments of deposition.--Sections 1 and 2 (Figure 7 and 8; Appendix A) are interpreted to represent a transition from marine to brackish water environments in a deltaic front-distributary channel complex (see "Interpretations of environments from measured sections 1 and 14," p. 54).

A fluvial-floodplain environment is suggested for sections 3, 5 to 10, 12, 14, and 15. Fining-upward sequences are common, with lithologies ranging from conglomerate to mostly siltstone and claystone. Primary sedimentological features include small-scale, low and high angle, cross laminations in fine-grained sediment. ?*Planorbula* aff. *P. armigera* and ?*Stagnicola* sp. may suggest shallow (less than 1 m) ponds or marshes nearby. The presence of *Musculium lacustre* and *M. transversum* suggests that aquatic vegetation was possibly present. The identified ostracodes probably represent a marginal fluvial (probably freshwater) environment consisting of possibly ponds, small lakes, marshes, slow sluggish streams or floodplains that may have been connected to an estuarine-delta complex. In general, the ostracodes were not living in the fluvial channel (Forester 1980). Deltaic distributary complexes may also have been present.

A fluvial-channel environment is suggested for sections 11, 13, and 16 to 18. Sedimentological evidence includes channels, erosional lower contacts, with fining-upward sequences filling the channels. The lithology ranges from conglomerate to poorly sorted wacke. ?*Planorbula* aff.

P. armigera, and ?Stagnicola suggest shallow (less than 1 m) ponds or marshes, and Musculium lacustre suggests aquatic vegetation nearby. Ostracodes were probably transported from a marginal fluvial environment. The presence of fish in section 11 suggests permanent water nearby.

A nearshore lacustrine, low energy, fluvial or prodelta-front type of environment is suggested for sections 4 and 19 to 23. The similar lithologies of fine- and very fine-grained sandstone, siltstone, and claystone, combined with fining-upward sequences and parallel or cross laminations, suggest these environments. Fossils include Musculium transversum, plants, and several fresh- to brackish-water fish (Harper 1980), suggesting permanent water with aquatic vegetation.

The absence of molluscs in the mudstone of the lower Peace Valley "beds" (lacustrine facies), as compared to their presence in the nearly stratigraphically equivalent sandstone and siltstone of the lower Ridge Route "formation" (fluvial-deltaic facies), may suggest fluctuating salinities in the lacustrine environment with penecontemporaneous stable conditions in the fluvial-deltaic environment. Alternative explanations are that the lacustrine environment was too deep below the photic zone to support molluscan life, reducing conditions existed in the lacustrine environment, or that the sediment influx was too great from the San Gabriel fault zone and the deposition of the Violin Breccia with increased turbidity inhibiting growth of molluscs. The absence of molluscan fossils in the coarse-textured sediments along the far eastern portion of the Ridge Route "formation," compared with stratigraphic equivalents (fluvial facies) higher and lower along the Old Ridge Route road, probably represents a high sediment influx environment (alluvial fan facies) uninhabitable by molluscs.

Interpretations of environments from measured sections 1 and 14.--Section 1 (Figure 7) is interpreted as a deltaic front-distributary channel complex of marine to freshwater environments. Evidence for a marine environment includes a transported *Chlamys* (*Chlamys*) cf. *C.* (*C.*) *hodgei* (marine pecten) in a turbidite deposit about 50 m stratigraphically below the base of measured section 1. Sedimentological evidence for this interpretation for units 1-7 includes soft sediment deformation, conglomerates, rip up clasts, well sorted arenites with few wackes, low angle, planar and trough-shaped, cross bedding, and gypsum beds. The presence of low angle, planar and trough-shaped, cross bedding in well sorted arenites is interpreted to represent unidirectional currents (e.g., turbidite, fluvial or distributary bars). Fluvial or turbidity currents are suggested by the presence of conglomerates and rip up clasts. Soft sediment deformation is suggestive of subaqueous sediment overloading on a fan-delta front, and the presence of gypsum (if of primary origin) suggests subaerial exposure of brackish or marine sediment, eliminating a fluvial environment.

Units 8 to 17 were probably deposited in a brackish water environment, as suggested by the presence of *Tryonia* aff. *T. protea* (a freshwater to brackish-water form) and *Cyprideis* aff. *C. beaconensis* with smooth tests, which indicates an estuarine environment (Forester 1979, 1980). Sedimentological evidence in units 8 to 17 for a similar depositional environment as that of units 1 to 7 consists of small-scale, trough-shaped cross laminations, well sorted arenites fining-upward to wacke and siltstone, channels, rip up clasts, groove casts, sole marks, and burrows. The Ridge Basin probably became closed to marine influence and was diluted with freshwater inflow at this time. An alternate (less likely) explanation for the occurrence of Tryonia and Cyprideis is that the water was already brackish and sediment influx decreased or that the environment became shallow enough to support Tryonia and Cyprideis.

Units 18 to 26 consist of coarser sediment and more channels than lower in the section. Sedimentological features are channels, conglomerates, rip up clasts, an increased amount of plant fragments, charcoal, and more burrows. The environment of deposition probably included a prograding delta-distributary complex grading into a less saline basin or fluvial overbank system. Fontelicella aff. F. (F.) truckeensis and two other hydrobiids suggest freshwater and aquatic vegetation. Cyprideis aff. C. beaconensis (some noded) suggest a decrease in salinity from the underlying units (Forester 1979). This interpretation is in agreement with that of Link and Osborne (1978, p. 182).

Section 14 (Figure 10) is interpreted to represent a fluvial-point bar-floodplain environment complex. The sedimentological evidence for this interpretation consists of small-scale, low and high angle, grouped, trough-shaped cross laminations in fine-grained wacke, with channels of conglomerate with large-scale, low angle, cross bedding, and rip up clasts. The sections are finer-grained upwards to fine-grained cross-bedded wacke and siltstone. Well sorted arenite is also present.

Grouped, trough-shaped cross laminations in fine-grained wacke are interpreted to represent fluvial ripples. Well sorted arenite is considered to be texturally mature and is usually representative of fluvial or high energy beach environments. Fining-upward cycles from conglomerate to wacke and siltstone generally represent fluvial or turbidity current environments and is here suggested to represent a fluvial environment because of the textural maturity (arenite), cross laminations in the siltstone and wacke (unlike Bouma sequences), and trough-shaped cross laminations in the fine-grained wacke. An overbank or floodplain environment is suggested because of the large amount of fine- and very fine-grained wacke and siltstone.

Shallow (less than 1 m) freshwater ponds or marshes may be suggested by ?Stagnicola and ?Planorbula aff. P. armigera. Aquatic vegetation is suggested by Musculium lacustre. The ostracodes probably represent a pond-marsh habitat in a marginal fluvial setting that could be associated with an estuarine-delta complex (Forester 1979, 1980).

CONCLUSIONS

The nonmarine molluscs of the Ridge Route "formation" and Peace Valley "beds" consist of ten species: one unionid, Anodonta oregonensis; three sphaeriids, Musculium lacustre, M. transversum, and Pisidium (Cyclocalyx) nitidum; four hydrobiids, Fontelicella aff. F. (F.) truckeensis, Tryonia aff. T. protea, and Hydrobiidae species 1 and 2; one lymnaeid, ?Stagnicola sp.; and one planorbid, ?Planorbula aff. P. armigera.

All of the hydrobiids occur stratigraphically in the lower portion of the Ridge Route "formation" and Peace Valley "beds." The other nonmarine molluscs occur in the Ridge Route "formation" and Peace Valley "beds" above the hydrobiids except in measured section 3, where Fontelicella aff. F. (F.) truckeensis and Hydrobiidae species 2 are associated with Musculium lacustre, M. transversum, and ?Planorbula aff. P. armigera.

Ridge Route and Peace Valley molluscs occur in sediment ranging from claystone to conglomerate although the majority of the molluscan fauna occurs in siltstone, very fine-grained wacke, and claystone. The absence of molluscs in the mudstone of the lower Peace Valley "beds" (lacustrine facies), as compared to the presence of the fauna in the nearly stratigraphic equivalent sandstone and siltstone of the lower Ridge Route "formation" (fluvial-deltaic facies), may suggest fluctuating salinities in the lacustrine environment with penecontemporaneous stable salinity conditions in the fluvial-deltaic environment. Alternative explanations are that the lacustrine environment was too deep below the photic zone to support molluscan life or that the sediment influx was too great from the San Gabriel fault zone and the deposition of the Violin Breccia. The absence of molluscan fossils in the coarse-textured sediment along the far eastern portion of the Ridge Route "formation," compared with approximate stratigraphic equivalents (fluvial facies) higher and lower along the Old Ridge Route road, probably represents a high sediment influx environment (alluvial fan facies) uninhabitable by molluscs.

Ridge Route and Peace Valley nonmarine molluscs do not suggest an age for the basin, as all of the nonmarine molluscs are represented in modern environments. Chlamys (Chlamys) cf. C. (C.) hodgei, from the lowermost portion of the Ridge Route "formation," has been reported from late Miocene deposits (Wilson 1978). The ostracodes probably indicate a late Miocene age for the Ridge Route "formation" and Peace Valley "beds" (Forester 1980). Vertebrates suggest a Miocene to Pliocene age for the Ridge Basin Group and the paleoflora suggests a Pliocene age for the middle of the Group. Recent manetostratigraphy suggests an early Pliocene age for the lowermost Ridge Basin Group (Ensley and Verosub 1979).

Freshwater environments are indicated by the presence of Anodonta, Musculium, Pisidium, Fontelicella, ?Stagnicola, and ?Planorbula. Stagnant water is indicated by the presence of ?Stagnicola and ?Planorbula. Brackish water environments may be indicated by the presence of Tryonia or hydrobiids. Shallow freshwater is suggested by the presence of ?Planorbula aff. P. armigera and Pisidium (Cyclocalyx) nitidum. ?Stagnicola, together with ?Planorbula aff. P. armigera, is assumed to represent shallow freshwater ponds or marshes on a floodplain.

Measured sections 1 and 2 are interpreted to represent a transition from marine to brackish and possibly freshwater environments in a deltaic front-distributary channel complex. A fluvial-floodplain environment is suggested for measured sections 3, 5 to 10, 12, 14, and 15, sections 11, 13, and 16 to 18, with shallow freshwater (less than 1 m) ponds or marshes nearby. Either a nearshore lacustrine, prodelta lacustrine, or low energy fluvial environment is suggested for sections 4 and 10 to 23.

SYSTEMATIC PALEONTOLOGY

The classification to subfamily for the pelecypods is after Clarke (1973); for the gastropods, Taylor and Sohl (1962) are followed. The synonymies used here are abbreviated and include the most recent works available with complete descriptions or diagnostic illustrations. Older references are cited if they contain complete descriptions with diagnostic illustrations and the recent publications lack them. Taxonomic differences are discussed under the heading "Discussion," as well as geologic and geographic ranges where they are expanded. Measurements are within 0.5 mm where possible or were estimated for nearly complete specimens. A question mark with a species name represents doubt in part or all of the assignment, following Bishop et al. (1978).

The collection is housed in the Los Angeles County Museum of Natural History (LACMNH), Invertebrate Paleontology. Accession numbers used are from the LACMNH and are represented by a four digit numeral. Because the LACMNH does not assign hypotype numbers to figured specimens in unpublished manuscripts, a manuscript number (Ms type) is used to separate figured specimens from the remainder of the collection.

Phylum MOLLUSCA

Class PELECYPODA

Order EULAMELLIBRANCHIA

Superfamily UNIONACEA

Family Unionidae

Subfamily Anodontinae

Genus Anodonta Lamarck, 1799

Diagnosis.--"Shells uniformly thin or thin posteriorly and thickened anteriorly. Most species are elliptical or ovate but in some species a posterio-dorsal projection or 'wing' is well developed. Hinge without teeth in all species and hinge line straight or evenly convex. Beak sculpturing single or double-looped and consisting of 4 or 5 parallel bars . . ." (Clarke 1973, p. 50).

Anodonta oregonensis Lea, 1838

Pl. 1, figs. 12, 19-21

Anodonta oregonensis Lea 1838, p. 80-81, pl. XXI, fig. 67; Simpson 1914, p. 375-376; Henderson 1924, p. 85, fig. 1; Burch 1975b, p. 76-78, fig. 121.

Anodonta cygnea (part), Hannibal 1912, p. 125, pl. V, figs. 3, 4, 8.

Diagnosis.--Shell narrowly elliptical, length/height ratio usually less than 2.0; scarcely inflated, primarily over median portion; dorsal wing slightly developed, angled and obliquely truncate behind; posterior end of shell pointed; height of posterior half nearly equal to height of anterior half; bars of beak sculpture even in height (modified from Simpson 1914, p. 384; Burch 1975b, p. 76, 78).

Description of material.--Measured shells are 13-65 mm long ($\bar{x}$=35.1, n=99), 9-38.5 mm high ($\bar{x}$=21.1, n=113) and of 5-16.5 mm wide ($\bar{x}$=9.8 mm, n=20). Length/height ratios are 1.2-2.1 ($\bar{x}$=1.7, n=95).

Shells are mostly elliptical, and posterior margins are slightly pointed. Height of the posterior half is nearly equal to the anterior half, and the anterior half is less inflated than the maximum inflation, which is posterior of the umbone. Shells have a moderate to less than moderate wing that is low and truncated behind. Beaks are compressed, barely elevated above the hinge line, and are located one-fifth of the distance back from the anterior margin. Shells have four or less beak ridges that are double-looped with even bars parallel to the straight hinge.

Discussion.--Anodonta oregonensis has previously not been reported south of Salmon Creek, Marin County, California (Gregg 1947). It most closely resembles A. californiensis, a southern California species that has a considerably developed dorsal wing (Simpson 1914, p. 376). The posterior half of the shell is higher than the anterior half and the length to height ratio is 1.5 or less (Burch 1975b, p. 76). A. beringiana is inflated only over the anterior half (Burch 1975b, p. 76), and the dorsal wing is scarcely developed (Gregg 1947, p. 8). A. kettlemanensis is subtrapezoidal and has a nearly rectangularly truncated posterior extremity (Arnold 1909, p. 91).

Ecology.--A. oregonensis is commonly found in lakes (Hemphill 1891, p. 326; Roscoe 1961, p. 23-24; Martin and Mehringer 1965, p. 435; Mullineaux et al. 1965, p. 4) but occurs also in ponds (Hemphill 1891, p. 326; Ortmann 1913-1916, p. 43), and rivers (Lea 1838; Hemphill 1891; Jones 1940, Mullineaux et al. 1965).

The diet of Anodonta spp. primarily consist of detritus and zooplankton (Fuller 1974, p. 221). According to Fuller (1974, p. 221), mature larvae (glochidia) attach to host fish for a time and then drop off to survive on suitable substrates. Suitable substrates are non-shifting sands and unsuitable substrates are mud or shifting sands. The host fish for Anodonta oregonensis is not known. At least 12 families of fishes serve as host for other Anodonta; the Cyprinidae serves at least three of these (Fuller 1974, p. 232-233).

Superfamily SPHAERIACEA

Family Sphaeriidae

Genus Musculium Link, 1807

Diagnosis.--Adult specimens about 6-14 mm long, shell walls thin to moderately thick, striae fine, shell truncate posteriorly and without a low, radiating, internal rib; beaks anterior; umbones usually calyculated (modified from Clarke 1973, p. 151; Burch 1975a, p. 9; Heard 1977, p. 451).

Musculium lacustre (Müller), 1774

Pl. 1, fig. 13, 15

Spherium lacustre (Müller) Herrington 1962, p. 19, pl. II, fig. 1.

Spherium (Musculium) lacustre (Müller) Clarke 1973, p. 152, pl. 16, fig. 9.

Musculium lacustre (Muller) Burch 1975, pp. 9-11, fig. 9a.

Diagnosis.--Shell up to about 13 mm long, relatively fragile, trapezoidal to rhomboidal, length/height ratio about 1.1, with prominent, projecting umbones, rounded dorsal margin, and broadly-curved ventral margin (modified from Clarke 1973, p. 152; Burch 1975a, p. 11).

Description of material.--Measured shells are 4.7-8.8 mm long ($\bar{x}$=6.5, n=6) and 3.7-8.0 mm high ($\bar{x}$=5.2, n=6), with length/height ratios of 1.1-1.5 ($\bar{x}$=1.3).

The thin trapezoidal shells have a shorter dorsal margin than ventral margin, both with broad curves. Posterior regions are generally higher than anterior regions with anterior margins subelliptical and posterior margins subtruncate to truncate. Shells are moderately inflated with the maximum inflation at the umbonal region. Slope is steeper on the anterior side of the umbone than on the posterior. Beaks, somewhat anterior, are prominent, rise above the dorsal line and may or may not be calyculated. Exterior surface of the shells is smooth with many fine, even growth striae. Anterior laterals are less curved and shorter than posterior laterals.

Discussion.--One specimen differs slightly from the remainder of the material by having a straighter dorsal margin. Probably this specimen is a *M. partumeium* although it can not be separated on only one characteristic.

Ecology.--*Musculium* exhibits adaption for life in rigorous ephemeral habitats (Heard 1977, p. 451). According to Burch (1975a, pp. 34-35), *M. lacustre* is mostly found in "ponds and small lakes on a muddy substrate, but also found in large lakes, and in creeks and rivers. . . ." *M. lacustre* is more tolerant of adverse habitats than other species of *Musculium* (Ellis 1962, in Burch 1975a, p. 35). Clarke (1973, p. 154) observed submerged vegetation of varying accounts at all 75 of his *M. lacustre* localities.

Musculium transversum (Say), 1829

Pl. 1, figs. 14, 16

Spherium transversum (Say) Herrington 1962, p. 29, pl. II, fig. 6.

Spherium (Musculium) transversum (Say) Clarke 1973, p. 160, pl. 16, fig. 3.

Musculium transversum (Say) Burch 1975a, pp. 8-11, fig. 8a.

Diagnosis.--Shell greater than 8 mm long, fragile, relative elongate (length/height ratios of 1.3 or more) (modified from Clarke 1973, p. 160; Burch 1975a, p. 11).

Description of material.--Measured shells are 4.2-9.0 mm long ($\bar{x}$=5.8, n=19) and 2.7-9.0 mm high ($\bar{x}$=4.5, n=14), with length/height ratios of 1.2-1.7 ($\bar{x}$=1.4, n=14).

Thin, elongate shells have a gently convex ventral margin that is considerably longer than the long, nearly straight dorsal margin. The anterior margin is subelongate and the posterior margin is subtruncate. Inflation is low to moderate with maximum inflatedness in the umbonal region. Beaks are anterior of center, usually calyculated, and elevated above the dorsal line. Fine growth striae are slightly irregular. Right posterior laterals are longer than right anterior laterals, with cusps (P I and P III) distal. Right anterior laterals bend toward the apex of the umbone.

Ecology.--M. transversum is generally found in large lakes, rivers and sloughs with bottoms usually of mud but may be of sand and gravel (summarized from other workers by Burch 1975a, p. 35). Clarke (1973, p. 162) reported M. transversum from large lakes and rivers with sparse to moderately abundant vegetation and slow to moderate currents. M. transversum seldom inhabits temporary ponds (Gale 1977, p. 12).

Genus Pisidium Pfeiffer, 1821

Diagnosis.--"Shells very small (2 mm) to medium-sized (12 mm), ovate but asymmetrical in most species (with anterior produced and posterior abruptly rounded), slightly inflated to globose, and with umbones located posterio-dorsally" (Clarke 1973, p. 163).

Subgenus Cyclocalyx Dall, 1903

Diagnosis.--"Shell medium-sized (3 to 6 mm) and with thick to thin walls" (Clarke 1973, p. 169).

Pisidium cf. P. (C.) nitidum Jenyns, 1832

Pl. 1, figs. 7, 8

Pisidium nitidum Jenyns. Herrington 1962, p. 45, pl. V, fig. 6.

Pisidium (Cyclocalyx) nitidum Jenyns. Clarke 1973, p. 191, pl. 18, fig. 7; Burch 1975a, p. 17, fig. 21c.

Diagnosis.--Shell up to 3.2 mm long, ovate-rhomboid, rather thin, with low, subcentral umbones, nearly straight ventral margin, and distal anterior cusps (modified from Clarke 1973, p. 191).

Description of material.--Measured shells are 2.0--2.8 mm long ($\bar{x}$=2.4, n=12) and 1.8-3.0 mm high ($\bar{x}$=2.2, n=12), with length/height ratios of 0.9-1.5 ($\bar{x}$=1.1).

Thin, subtriginal shells have nearly straight, short antero-dorsal margins and broadly convex ventral margins. Anterior margins are narrowly convex and posterior margins are moderately convex. Inflation is moderate, more posteriorly than anteriorly, with maximum inflation occurring at the umbones. Umbones are not prominent and are slightly to considerably posterior of center. Striae are moderately fine and regular. The hinge is slightly curved and cusps of the laterals are distal.

Discussion.--Ridge Basin material was primarily described from molds of the interior. Comparisons of dentition could not be made because cardinal teeth were not observed, and the cusps of the laterals were not well preserved. This material resembles P. (C.) nitidum form pauperculum Sterki of Clarke (1973, p. 191) in shape (triginal), and has a hinge that is heavier than in P. (C.) nitidum s. str. although not as heavy as in the form pauperculum.

Ecology.--P. (C.) nitidum Jenyns has been reported from large and small lakes (Clarke 1973, p. 191), ponds (Herrington 1962, p. 46; Clarke 1973, p. 191), and creeks and rivers (Herrington 1962, p. 46; Clarke 1973, p. 191). Bottom sediments range from mud to boulders with depths less than 3.7 metres (Baker 1928). Herrington (1962, p. 46) said that the form pauperculum seems to prefer shallow water and Clarke (1973, p. 191) reported the form pauperculum from waters with abundant to no vegetation.

Class GASTROPODA

Subclass STREPTONEURA

Order MESOGASTROPODA

Superfamily RISSOACEA

Family Hydrobiidae

Genus Fontelicella Gregg and Taylor, 1965

Diagnosis.--Shell 2.5-8 mm long in adults, rimate or imperforate, narrowly elongate to conic or globose, with 3-6 whorls; aperture

20-40% of total shell length. No sculpture except for minute growth striae (modified from Gregg and Taylor 1965, p. 103-104).

Subgenus Fontelicella Gregg and Taylor 1965

Diagnosis.--Shell small for the genus (2.5-5 mm long, 3-4 whorls in adults) (modified from Gregg and Taylor 1965, p. 107).

Fontelicella aff. F. (F.) truckeensis Yen, 1950

Pl. 1, figs. 2, 3

Hydrobia truckeensis Yen 1950, p. 186.

Fontelicella (F.) truckeensis Gregg and Taylor 1965, p. 108.

Diagnosis.--Shell minute (length =2.0 mm, width =1.3 mm, 3.5-4 whorls, n=2), subovate; spire longer than ultimate whorl. Whorls strongly convex, moderately abruptly increasing in size, with fine growth lines. Aperture with continuous peristome. Umbilicus narrowly perforate (modified from Yen 1950, p. 186.)

Description of material.--Measured shells are 0.8-3.3 mm long ($\bar{x}$=1.9 mm, n=52) and 0.5-2.2 mm wide ($\bar{x}$=1.2 mm, n=52), with length/width ratios of 1.0-2.4 mm ($\bar{x}$=1.6 mm, n=51).

Thin shells have three strongly convex, abruptly expanding, unshouldered whorls. Protoconchs are conical and spires are equal to or slightly longer than the ultimate whorl. Sutures are slightly impressed and whorls lack sculpture although faint growth lines are present.

Discussion.--Ridge Basin material differs from Fontelicella micrococcus, which is more inflated and has a more obtuse apex (Hanna 1922, p. 10-11). F. (F.) truckeensis is also smaller than most of the other species of Fontelicella. About one-third of the specimens seem to have sutures on the spire oblique to the suture of the ultimate whorl.

Ridge Basin material is questionably assigned to F. (F.) truckeensis because most of the material is poorly exposed and no apertures were observed. Also, Yen's (1950, p. 186) original species description is incomplete.

Ecology.--Fontelicella (F.) sp. has been reported living in "small springs, seepages or in small streams on soft mud among dense aquatic plants or, on rocks or sticks" (Gregg and Taylor 1965, p. 107).

Genus Tryonia Stimpson, 1865

Diagnosis.--Shell turreted, elongated, shouldered, may consist only of growth lines, or may be coarsely lirate, plicate or reticulate. Shell perforate, aperture small, peristome continuous. Spines absent on shoulders (modified from Stimpson 1865, p. 49; Taylor 1966a, p. 196).

Tryonia aff. T. protea Gould, 1855

Pl. 1, figs. 5, 6

Amnicola protea Gould 1855, p. 129

Melania exiqua Conrad 1855, p. 269.

Tryonia protea Stearns 1901, p. 277.

Diagnosis.--Shell elongate, seven to eight whorls, divided by a deep suture, variously ornamented with revolving ridges and longitudinal folds. Aperture ovate, peristome continuous and barely touching the penultimate whorl. Maximum length is 7.6 mm (modified from Binney 1865, p. 71).

Description of material.--Measured shells are 1.8-4.8 mm long ($\bar{x}$=3.0 mm, n=95) and 1.0-2.7 mm wide ($\bar{x}$=1.7 mm, n=103), with length/

width ratios of 1.2-2.5 ($\bar{x}$=1.8, n=95) and aperture length/width ratios of 0.5-1.3 ($\bar{x}$=0.8, n=23).

Shells have three to five and one-half whorls, are turreted, elongate and acutely shouldered. Spires are elevated and nuclear whorls are usually planispiral and squarish at the apex with well-impressed sutures. Axial ribs are present on all except the abapical one-third to one-half of the ultimate whorl and on the nuclear and second whorl. Spiral lirae are evenly spaced on the adapical portion of whorls and absent or inconspicuous on the abapical portions of the whorls. Shells are perforate and the apertures are usually ovate although they may be circular, with peristome complete, slightly flared abapically, and barely touching the penultimate whorl.

Discussion.--Ridge Basin material most closely resembles living Tryonia protea found in the Colorado Desert of southeastern California (Stearns 1901, p. 277). It does not resemble Pyrgophorus blankeana or P. caluillarum of Taylor (1950, p. 30-31), that he later named T. protea (Taylor 1966a, p. 196). Ridge Basin material differs from T. protea, which has eight whorls, a maximum length of 7.6 mm and maximum width of 2.5 mm (Binney 1865, p. 71-72). This material differs from that of Stearns (1901, p. 277) by having fewer whorls and less elevated lirae. It is highly probable that the Ridge Basin material is a new species.

Tryonia clathrata, the type species, is different in having no revolving lirae and an acute apex (Stimpson 1865, p. 48). T. bakeri is similar although the length/width ratio is greater than 2 and the whorls are very convex (Pilsbry 1891, p. 328). The most diagnostic characteristics of the Ridge Basin material are the turreted square shoulders with axial ribs and fine, evenly spaced, spiral lirae.

Ecology.--*Tryonia* sp. is found living in the high plateaus of southwestern North America and Central America where extensive late Tertiary basins existed. Most of these basins presently have internal drainages or drain into the Pacific Ocean (Taylor 1966a, p. 196). *T. protea* has been reported from freshwater and brackish springs and spring outflows (Stearns 1901, p. 277; Keep 1911, p. 315; Chamberlin and Jones 1929, p. 178; Keep and Baily 1935, p. 204-205; Russell 1971, p. 232) and from Pleistocene Lake Bonneville (Roscoe 1961, p. 26).

Family Hydrobiidae

Diagnosis.--Conispiral or cyclindrispiral shells; minute to small, 1-6 mm long, rarely over 10 mm. Dextral coiling with about 2-8 whorls and aperture may be thickened within, deflected, or flared. Shell smooth in most genera except for collabral growth lines (modified from Taylor 1966a, p. 168; Clarke 1973, p. 240).

Species 1

Pl. 1, fig. 1

Description of material.--Measured shells are 0.8-1.2 mm long ($\bar{x}$=0.9 mm, n=4) and 0.6-1.0 mm wide ($\bar{x}$=0.8 mm), with length/width ratios of 1.1-1.3 ($\bar{x}$=1.2).

Conic shells have 3-4 rounded whorls. Shells are dextral with the nuclear whorl elevated above the other whorls. Remaining whorls are slightly shouldered adapically and are inflated. Spires are shorter than the ultimate whorl. Sutures are well impressed and the last whorl is inflated and rounded abapically. One specimen displays faint spiral striae.

Discussion.--Ridge Basin material is too poorly exposed and too few specimens exist (n=4) to make a positive identification. Species 1 is similar to Syncera compacta, which also has a spire shorter than the ultimate whorl and a similar convexity on the ultimate whorl (Bartsch 1920, p. 163).

Ecology.--"Nearly all Hydrobiidae are freshwater snails. Some are brackish-water, none strictly marine" (Taylor 1966a, p. 169).

Species 2

Pl. 1, fig. 4

Description of material.--Measured shells are 1.9-3.3 mm long ($\bar{x}$=2.5, n=6) and 1.0-2.1 mm wide ($\bar{x}$=1.4 mm), with length/width ratios of 1.5-2.3 ($\bar{x}$=1.8).

Conispiral shells are dextral and have 4-6 whorls. The ultimate whorl is rounded, whereas whorls of the spire are flat sided but not shouldered. The spire is longer than the ultimate whorl and sutures are well impressed.

Discussion.--The scanty Ridge Basin material is poorly exposed and apertures cannot be seen.

Ecology.--"Nearly all Hydrobiidae are freshwater snails. Some are brackish-water, none strictly marine" (Taylor 1966a, p. 169).

Subclass EUTHYNEURA

Order BASOMMATOPHORA

Superfamily LYMNAEACEA

Family Lymnaeidae

Genus Stagnicola (Leach) Jeffreys, 1830

Diagnosis.--"Shell elongate to short-ovate; outer lip generally somewhat thickened within; columella distinctly plicate; inner lip appressed; axis slightly or not at all perforate; surface with strong spirally impressed lines" (La Rocque 1966-70, p. 437).

?Stagnicola sp.

Pl. 1, figs. 17, 18

Description of material.--Measured shells are 7.0-32.6 mm long ($\bar{x}$=18.0, n=29) and 2.7-21.1 mm wide ($\bar{x}$=11.3, n=64), with length/width ratios of 1.4-2.6 ($\bar{x}$=1.7, n=27).

Thin conispiral shells are elongate-ovate, dextral, and have three to five whorls. Protoconchs are conical and whorls expand abruptly in size. Whorls are slightly convex and have rounded shoulders adapically. Spires are one-third of the total length and sutures are abutted to slightly impressed. Sides of the ultimate whorl have irregular, fine growth lines. Apertures are elongate-ovate and the columnar axis may be twisted.

Discussion.--Most of the Ridge Basin material is poorly exposed or difficult to extract from the matrix although three specimens exhibit near perfect spires. Apertural and umbilical views are missing. One specimen shows a portion of the columella suggesting the possibility of a twisted axis (Plate 1, Figure 17).

This material differs from Lymnaea which is ovately-oblong or elongate, has the last whorl expanded, has numerous fine spiral lines, and has an attenuated spire (Baker 1928, p. 196-197).

Ecology.--Stagnicola has been found in lakes, ponds, streams and pools. A few species prefer stagnant pools which may become dry in summer (Baker 1928, p. 210).

Superfamily ANCYLACEA

Family Planorbidae

Genus Planorbula Haldeman, 1840

Diagnosis.--Shells medium-sized to small, dextral, planorbid, with rounded or subcarinate whorls, and with at least one set of five to six lamellae within the aperture (modified from Clarke 1973, p. 419).

?Planorbula aff. P. armigera (Say), 1821

Pl. 1, figs. 9-11

Planorbis armigerus Say 1821, p. 164.

Planorbula armigera (Say) Baker 1928, p. 355, pl. VIII, figs. 27-30; Clarke 1973, p. 419, pl. 26, figs. 4-6.

Diagnosis.--Shell planorbiform, small, whorls rounded and subcarinate, spire somewhat concave, ultimate whorl deflected to left near aperture, and with six unequal lamellae within and behind aperture (modified from Clarke 1973, p. 419).

Description of material.--Two measured shells are 1.8 and 2.5 mm long; other measured shells are 6.2-8.0 mm wide ($\bar{x}$=6.8, n=4).

Planispiral shells are dextral and have up to four whorls. Protoconchs are depressed and whorls expand abruptly. Whorls are flattened on the right and strongly convex on the left side. The whorl profile has its greatest convexity near the right side, the least convexity towards the left side, and the last whorl is deflected to the left. Sutures are well impressed and the sides of the whorls have regular, fine growth lines. Apertures are longer than wide and are subtriangular to subovate. Umbilical regions are funicular.

Discussion.--Ridge Basin material is questionably assigned to Planorbula because the most diagnostic characteristic, internal lamellae, was not observed. Ridge Basin material differs from P. armigera by having less deflection and less abrupt deflection of the last whorl, and a slightly narrower umbilicus, with the penultimate whorl being less exposed there. One specimen suggests a thickening of the outer lip as in P. armigera.

P. armigera has not been reported from west of the Rocky Mountains (Baker 1928; Clarke 1973), and the oldest known fossil occurrence of P. armigera is the late Nebraskan or earliest Aftonioan (Pleistocene) (Taylor 1960, p. 37). The only occurrences of Planorbula west of the Rocky Mountains in the United States are P. campestris in recent sediments (Taylor 1966b, p. 89) and P. mojavensis in the Miocene Barstow formation of southern California (Taylor 1954, p. 71).

Ecology.--Planorbidae is a family of pond and marsh snails (Taylor 1966b, p. 90). P. armigera has been reported from swales, small, stagnant bodies of water (Baker 1928, p. 358), and slow-moving lotic environments among vegetation (Clarke 1973, p. 422). P. armigera seems to prefer mud bottoms but can live in grassy meadows (Baker 1928, p. 358), and is seldom found in water depths greater than one metre (La Rocque 1966-1970, p. 507).

EXPLANATION OF PLATE 1

Ridge Basin molluscs

(Figures 1-10, 15 X8; 11, X4.7; 12-14, 16, X5; 17-21, X2)

Figs. 1--Hydrobiidae, species 1. Lateral view, 5692, Ms type 15.

2,3--Fontelicella aff. F. (F.) truckeensis Gregg and Taylor. 2, lateral view, 5693, Ms type 11; 3, lateral view, 5993, Ms type 12.

4--Hydrobiidae, species 2. Lateral view, 5963, Ms type 16.

5,6--Tryonia aff. T. protea Gould. 5, lateral view, 5689, Ms type 13; 6, apertural view, 5689, Ms type 14.

7,8--Pisidium cf. P. (Cyclocalyx) nitidum Jenyns. 7, latex cast of right interior illustrating lateral teeth, 5725, Ms type 9; 8, latex cast of left interior illustrating hinge line and single anterior lateral tooth, 5725, Ms type 10.

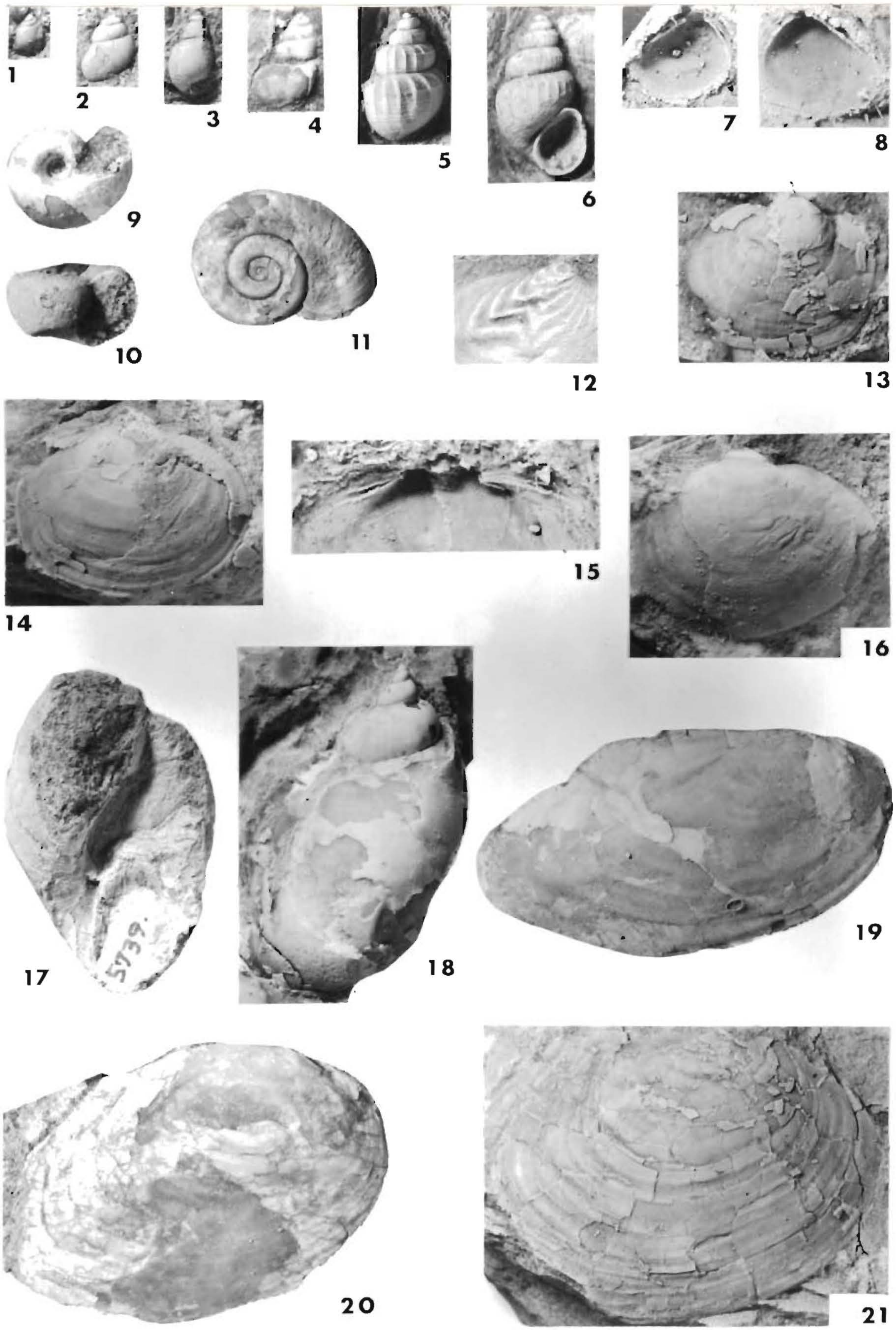
9-11--?Planorbula aff. P. armigera (Say). 9, 10, 5739, (specimen lost during photography); 9, view of left side (umbilical view); 10, apertural view; 11, view of right side, 5739 Ms type 19.

12,19-21--Anodonta oregonensis Lea. 12, latex cast of right exterior showing double-looped beak ridges, 5738, Ms type 1; 19, mold of right interior, 5739, Ms type 2; 20, mold of right interior, 5739, Ms type 3; 21, mold of right interior, 5744, Ms type 4.

13,15--Musculium lacustre (Müller). 13, mold of right interior illustrating capped umbone, 5697, Ms type 5; 15, latex cast of right interior illustrating lateral teeth, 5724, Ms type 6.

14,16--Musculium transversum (Say). 14, mold of right interior, 5697, Ms type 7; 16, exterior view of right valve, 5701, Ms type 8.

17-18--?Stagnicola sp. 17, apertural view with possible twisted columella, 5739, Ms type 17; 18, lateral view, 5738, Ms type 18.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
5739.
18
19
20
21

APPENDICES

APPENDIX A

DESCRIPTION OF MEASURED SECTIONS

SECTION 1

The base of section 1 (NW¼SE¼SW¼ sec. 27, T. 6 N., R. 17 W.) begins 4 m north of the stop sign (about 20 m north of Templin Highway) on the west side of the Old Ridge Route. The measured section extends about 0.2 km northwest along the west side of the Old Ridge Route. Accession numbers: 5684-5693; Figure 7 (columnar section).

Top of section Unit		Thickness (metres)
26.	Arenite, medium-grained; high angle cross bedding; channeled conglomerates; mudstone rip up clasts; grayish orange (10YR 7/4) to dark yellowish orange (10YR 6/6); great resistance to weathering	6.0
25.	Arenite, fine-grained; parallel laminations; and rare, small-scale, cross laminations; fining upward sequences; sole marks at base; grayish orange (10YR 7/4) to dark yellowish orange (10YR 6/6); moderate resistance to weathering; interbedded with siltstone, silty claystone, and claystone; laminations; medium dark gray (N4) to medium light gray (N6); slight resistance to weathering; fossils; burrows in arenite; plant and charcoal fragments abundant near base	2.4
24.	Siltstone; interbedded with claystone and silty claystone; parallel laminations; medium dark gray (N4) to medium light gray (N6); slight resistance to weathering; fossils: Charophyta abundant;	

SECTION 1 (cont.)

Fontelicella aff. F. (F.) truckeensis rare; Tryonia aff. T. protea rare; Hydrobiidae species 1 common; Hydrobiidae species 2 common; Cyprideis aff. C. beaconensis abundant; burrows uncommon 0.7

23. Arenite, conglomeratic; poorly sorted; uncommon pebble stringers; mudstone rip up clasts near base; massive bedding with floating boulders rare; grayish orange (10YR 7/4); great resistance to weathering 3.2

22. Claystone; massive; interbedded with silstone; cross laminations; medium gray (N5); slight resistance to weathering; fossils: plants common; Fontelicella aff. F. (F.) truckeensis common; Tryonia aff. T. protea uncommon; Hydrobiidae species 2 rare; Ostracoda abundant 0.4

21. Arenite, medium-grained; parallel laminations; pebble stringers; mudstone rip up clasts rare; grayish orange (10YR 7/4); moderate resistance to weathering 0.5

20. Claystone, silty; parallel laminations; medium light gray (N6); weathers to grayish orange (10YR 7/4); slight resistance to weathering; fossils: plant fragments uncommon 0.3

19. Arenite, medium-grained; moderately sorted; pebble stringers up to 30 cm long; pebbly channels; mudstone rip up clasts; small- and large-scale, low

SECTION 1 (cont.)

angle, cross bedding; grayish orange (10YR 7/4); moderate resistance to weathering; fossils: plant fragments and burrows near the base 1.1

18. Wacke, fine-grained; grains angular; cross bedding; grayish orange (10YR 7/4); overlain by silty clay; slight resistance to weathering; fossils: Fontelicella aff. F. (F.) truckeensis rare in upper silty clay; Hydrobiidae species 2 rare in upper clay; Tryonia aff. T. protea rare below Hydrobiidae species 2; Cyprideis aff. C. beaconensis abundant with Hydrobiidae species 2; burrows common in lower wacke 0.8

17. Siltstone; interbedded with claystone and silty claystone; medium gray (N5); slight resistance to weathering; fossils: Tryonia aff. T. protea abundant; Cyprideis aff. C. beaconensis common; burrows common below Tryonia horizon; overlain by 50 cm of medium-grained wacke; parallel laminations; grove cast and sole marks at base; grayish orange (10YR 7/4); moderate resistance to weathering; fossils: burrows rare; wood and charcoal fragments common 2.0

16. Arkosic arenite, very fine-grained; fining up to wacke; grayish orange (10YR 7/4); moderate resistance to weathering; interbedded with a 10 cm silty

SECTION 1 (cont.)

clay bed and another fining upward sequence; fossils: burrows rare in arenite 1.4

15. Arenite, medium-grained; poorly sorted; lower portion with large-scale channels; conglomeratic with clasts up to 15 cm in diameter; very large-scale, low angle, cross bedding; mudstone rip up clasts; upper portion is massive bedding; moderate resistance to weathering . 6.0

14. Arkosic arenite, fine-grained; well sorted; large-scale, low angle, cross bedding; grayish orange (10YR 7/4); moderate resistance to weathering; overlain by two silty clay beds (10 cm thick) with a very fine-grained arenite interbedded between the silty clays; medium gray (N5); slight resistance to weathering 1.3

13. Wacke, very fine-grained; very well sorted; parallel laminations; light gray (N7); moderate resistance to weathering; fossils (transported): ?*Tryonia* uncommon; overlain by 40 cm of interbedded, very fine-grained wacke, arenite, and clay; medium light gray (N6) to light olive brown (5Y 5/6); fossils (*in situ*); *Tryonia* aff. *T. protea* abundant in lowermost wacke; *Cyprideis* aff. *C. beaconensis* abundant (same horizon) 0.7

12. Wacke, very fine-grained; light gray (N7); fining upward to claystone; medium dark gray (N4); slight resistance to weathering; fossils (*in situ*):

SECTION 1 (cont.)

Tryonia aff. T. protea abundant; Ostracoda rare . . . 0.9

11. Arkosic arenite, fine-grained; well sorted; grains angular; subequant; channels of coarse- or medium-grained sand, fining upwards; rare, large-scale, high angle, cross bedding truncated by large-scale, low angle, cross bedding; mudstone rip up clasts near base; grayish orange (10YR 7/4); great resistance to weathering 2.9

10. Claystone; interbedded with silty claystone and rarely sandy claystone or siltstone; medium gray (N5); slight resistance to weathering; fossils (in situ): Tryonia aff. T. protea abundant; Ostracoda abundant 0.1

9. Wacke, very fine-grained; well sorted; small-scale, trough-shaped cross laminations; light gray (N7); moderate resistance to weathering 0.2

8. Wacke, very fine-grained; small-scale, low angle, trough-shaped, cross laminations; medium gray (N5); slight resistance to weathering; fossils (in situ): Tryonia aff. T. protea abundant; Cyprideis aff. C. beaconensis abundant at LACMNH 5684; Ostracoda abundant at LACMNH 5685 . . . . 0.5

7. Arenite, fine-grained; moderately well sorted; grains subangular; elongate; large-scale, low angle, planar, cross bedding; mudstone rip up clasts common near base; pebbles rare; grayish orange (10YR 7/4); moderately

SECTION 1 (cont.)

resistance to weathering with rare, great resistance to weathering beds; rare siltstone beds (less than 5 cm thick); light gray (N7) 4.2

6. Claystone, sandy; interbedded with very fine-grained wacke; thinly bedded (2-3 cm thick); solid gypsum layer at top; medium to light gray (N5-N7); slight resistance to weathering 0.7

5. Siltstone, sandy; medium gray (N5); interbedded with very fine-grained wacke; light olive gray (5Y 5/2); thinly bedded (10 cm thick beds of siltstone and less than 2 cm thick beds of wacke); slight resistance to weathering; overlain by medium-grained, arkosic arenite; grains subangular; subelongate; large- and small-scale, low angle, planar, cross bedding; overlain by high angle, trough-shaped; cross laminations; mudstone rip up clasts rare; dusky yellow (5Y 6/4); moderate resistance to weathering 1.4

4. Arkosick wacke, very fine-grained; well sorted; grains subangular; equant; parallel bedding; rip up clasts rare; large- and small-scale, soft sediment deformation; grayish orange (10YR 7/4); moderate resistance to weathering 1.6

3. Arkosic arenite; well sorted; grains subangular; equant; one bed of coarse-grained sand fining upwards to fine-grained arenite; sole marks;

SECTION 1 (cont.)

mudstone rip up clasts common; soft sediment deformation rare; grayish orange (10YR 7/4); moderate resistance to weathering; fossils (transported): pelecypod fragments; overlain by sandy siltstone; parallel bedding; gypsum beds rare; medium light gray (N6); slight resistance to weathering 1.2

2. Siltstone, sandy; interbedded with gypsum locally; parallel bedding; medium dark gray (N4) to light olive gray (5Y 5/2); slight resistance to weathering . . 3.6

1. Arkosic arenite, fine-grained; well sorted; grains angular; equant; large-scale, low angle, cross bedding and parallel bedding with gypsum at base; mudstone rip up clasts uncommon; large-scale soft sediment deformation; upper 2 m of conglomerate beds; grayish orange (10YR 7/4); moderate resistance to weathering 4.0

Total thickness 48.1

SECTION 2

Section 2 is about 0.5 km north of Templin Highway on the Old Ridge Route. The base of the section (SW¼NE¼SW¼ sec. 27, T. 6 N., R. 17 W.) begins at the second pullout north of Templin Highway about 5 m stratigraphically above the top of section 1, and extends to the west for about 0.1 km. Accession number: 5694; Figure 8 (columnar section).

Top of section Unit		Thickness (metres)
9.	Wacke, very fine-grained; interbedded with siltstone; medium light gray (N6 wet); slight resistance to weathering	1.2
8.	Quartz arenite, fine-grained; very well sorted; grains angular; subequant; well cemented; parallel laminations; dark yellowish orange (10YR 6/6); great resistance to weathering	1.4
7.	Claystone, silty; bedded; light olive gray (5Y 5/2 wet); slight resistance to weathering	0.4
6.	Wacke, fine-grained; moderately well sorted; some bedding; light olive gray (5Y 5/2 wet); slight resistance to weathering	2.7
5.	Claystone, silty; olive gray (5Y 3/2 wet); very weathered; interbedded with fine-grained wacke; slight resistance to weathering	2.2
4.	Quartz arenite; fine-grained; moderately well sorted; grains subangular; subequant; fining up; uncommon	

SECTION 2 (cont.)

large-scale, low angle, planar, cross laminations; dark yellowish orange (10YR 6/6 wet); moderate resistance to weathering 1.2

3. Claystone; interbedded with siltstone, silty claystone, and clayey siltstone; medium gray (N5); great resistance to weathering; fossils (transported): Fontelicella aff. F. (F.) truckeensis rare; Ostracoda rare; Vertebrata (?) 1.5

2. Arkosic arenite, medium-grained Conglomeratic; grains angular to rounded; large-scale, low angle, cross bedding with gravel channels uncommon; mudstone rip up clasts rare; grayish orange (10YR 7/4); great resistance to weathering 12.0

1. Quartz wacke, medium-grained; moderately well sorted; grains rounded; equant; grading laterally (south) into an arenite; moderate yellowish brown (10YR 5/4 wet); slight resistance to weathering 1.6

Total thickness 24.2

SECTION 3

Section 3 is about 8 km north of Templin Highway on the Old Ridge Route, and about 160 m southeast of benchmark 3186, on the east side of the Old Ridge Route. The base of the section (SE¼NW¼SW¼ sec. 8, T. 6 N., R. 17 W.) is poorly exposed and extends northwest (about 30 m) to a 1 m high outcrop under colluvium. Accession number: 5700; Figure 8 (columnar section).

Top of section Unit	Thickness (metres)
2. Claystone, silty; interbedded with clayey siltstone; well sorted; olive gray (5Y 4/1); slight resistance to weathering; fossils: _Musculium lacustre_ common; _M. transversum_ rare; _Fontelicella_ aff. _F._ (_F._) _truckeensis_ common; Hydrobiidae species 2 uncommon; ?_Planorbula_ aff. _P. armigera_ rare; _Cyprideis_ sp. uncommon; fish scales (Teleostei) rare	5.0
1. Arkosic wacke, medium-grained; poorly sorted; grains subangular; grayish orange (10YR 7/4); slight resistance to weathering	10.0
Total thickness	15.0

SECTION 4

Section 4 is about 8 km north of Templin Highway on the northeast side of the Old Ridge Route. The base of the section (NW¼NE¼NW¼ sec. 8, T. 6 N., R. 17 W.) is about 0.3 km southeast of the point where a natural gas pipeline crosses the road. Accession number: 5701; Figure 8 (columnar section).

Top of section

Unit		Thickness (metres)
6.	Wacke, silty fine-grained; poorly sorted; bedded; slight resistance to weathering	1.0
5.	Arkosic arenite, medium-grained; poorly sorted; grains angular, subelongate; graded bedding with granite clasts 5 cm in diameter at the base	1.0
4.	Claystone, silty; parallel bedding; olive gray (5Y 5/2); slight resistance to weathering; fossils: Plant and charcoal fragments common; ?*Musculium lacustre* rare; *M. transvesum* rare; Gastropoda uncommon; two interbedded arkosic wackes near top and one near base; medium-grained; poorly sorted; lower contact erosional; grayish orange (10YR 7/4)	3.3
3.	Wacke, arkosic?; silty, fine-grained; grayish orange (10YR 7/4); slight resistance to weathering .	1.0
2.	Claystone; mostly covered with soil and colluvium; bedding not apparent; moderate yellowish brown (10YR 5/4); slight resistance to weathering	2.3

SECTION 4 (cont.)

1.	Wacke, coarse-grained; poorly sorted; grains angular; subelongate; three graded sequences of 5 cm clasts up to sand, eroded and repeated; yellowish gray (5Y 7/2); great resistance to weathering	1.4
Total thickness	. . . .	10.0

SECTION 5

Section 5 is on the southwest side of the Old Ridge Route north of an east-facing road washout (rotational slump). The base of the section (NE¼SE¼SE¼ sec. 6, T. 6 N., R. 17 W.) is about 24 m north of the first ridge north of the washout and extends westward about 30 m. Accession number: 5702; Figure 8 (columnar section).

Top of section Unit	Thickness (metres)
13. Arkosic wacke, medium-grained; poorly sorted; grains subequant; dusky yellow (5Y 6/4); interbedded with and fining up to siltstone; medium light gray (N6); slight resistance to weathering	1.2
12. Arkosic wacke, fine-grained; moderately sorted; grains subrounded; equant; small-scale, low angle, cross bedding; uncommon pebbles; moderate resistance to weathering; fossils: Spheriidae? rare; ?<u>Stagnicola</u> sp. rare; grading up to siltstone; very fine-grained sandy; uncommon 5 cm thick wacke stringers; entire unit forms a dip slope; olive brown (5Y 5/4); slight resistance to weathering	3.5
11. Arkosic wacke, medium-grained; moderately sorted; grains subangular; subequant; large-scale, low angle, cross bedding with parallel bedding near top; fining up; grayish orange (10YR 7/4); great resistance to weathering	1.1

SECTION 5 (cont.)

10.	Arkosic wacke, fine-grained; thinly bedded; yellowish gray (5Y 7/2); interbedded with fine-grained sandy siltstone; medium light gray (N6); moderate resistance to weathering	0.5
9.	Arkosic wacke, medium-grained; poorly sorted; grains subrounded; equant; large-scale, low angle cross laminations but mostly parallel laminations; yellowish gray (5Y 7/2); moderate resistance to weathering .	0.3
8.	Siltstone; thinly interbedded with arkosic wacke; fine-grained; medium light gray (N6) to yellowish gray (5Y 7/2); moderate resistance to weathering . . .	0.1
7.	Arkosic wacke; same as unit 9; rare, small-scale, high angle, cross laminations	2.2
6.	Wacke, fine-grained; thinly interbedded with siltstone and silty claystone; 2 mm beds of gypsum; a 1 mm bed of charcoal fragments; medium light gray (N6) to yellowish gray (5Y 7/2); slight resistance to weathering	0.5
5.	Arkosic wacke, coarse- to fine-grained; poorly sorted; grains angular; subequant; large-scale, low angle, cross bedding throughout; uncommon fining upward sequences; base is channeled with mudstone rip up clasts at top of channels; yellowish gray (5Y 7/2); great resistance to weathering	4.1

SECTION 5 (cont.)

4.	Arkosic wacke, fine-grained; poorly sorted; grains subangular; subequant; grayish orange (10YR 7/4); moderate resistance to weathering	1.0
3.	Arkosic wacke; fines up to siltstone, very fine-grained; interbedded with siltstone, fine-grained sandy and silty claystone; dusky yellow (5Y 6/4); slight resistance to weathering	0.7
2.	Arkosic wacke, fine-grained; fining upward to fine-grained sandy, silty claystone; dusky yellow (5Y 6/4); slight resistance to weathering	0.7
1.	Quartz wacke, medium-grained; poorly sorted; grains angular; two graded cycles; ?channels; mudstone rip up clasts rare; grayish orange (10YR 7/4); great resistance to weathering	0.7
Total thickness		16.6

SECTION 6

Section 6 is located along the Old Ridge Route near the suspension bridge. The base of the section (SW¼NE¼SW¼ sec. 6, T. 6 N., R. 17 W.) begins about 200 m south-southeast of benchmark 3176 on the west side of the road. This is about 50 m up section from the top of section 5, in the first outcrop above the road. The section continues to benchmark 3176 where it crosses the road and continues northwestward along the northeast side about 100 m past the suspension bridge. Accession numbers: 5703-5712; Figures 8-9 (columnar sections).

Top of section Unit		Thickness (metres)
87.	Arkosic wacke, medium-grained; well sorted; grains subrounded; parallel bedding and small-scale, low angle, cross laminations (grouped planer); increasing matrix upward and repeat of section; grayish orange (10YR 7/4); great resistance to weathering; fossils: stromatolites abundant in upper metre; Ostracoda rare above stromatolites	5.5
86.	Claystone, silty; with clayey siltstone; rarely interbedded with very fine-grained wacke; medium olive gray (5Y 5/1) at base, up to light olive gray (5Y 6/1); slight resistance to weathering; upper 20 cm is very fine-grained wacke; thinly bedded	3.5
85.	Arkosic wacke, fine-grained; moderately well sorted; grains equant; light olive gray (5Y 6/1); grading up to very fine-grained wacke; overlain by fine-grained arkosic wacke; well sorted; grains angular; equant;	

SECTION 6 (cont.)

pale grayish orange (10YR 7/2); entire cycle repeated; all moderate resistance to weathering; fossils: concentrated charcoal abundant 40 cm from base 1.9

84. Wacke, fine-grained; moderately well sorted; light olive gray (5Y 5/2); grading up to sandy clay; medium dark gray (N4); all interbedded with fine-grained sandy claystone; slight resistance to weathering 2.3

83. Conglomerate; boulders up to 20 cm in diameter; very poorly sorted; bedded and massive; light olive gray (5Y 6/1); great resistance to weathering 3.6

82. Lithic arenite, fine-grained; very well sorted; small-scale, low angle, cross laminations; yellowish gray (5Y 7/2); slight resistance to weathering; covered at base for 4.1 m by a small debris flow and slope wash containing mostly wacke 0.3

81. Arenite, coarse-grained; poorly sorted; grains rounded; equant; pebbles up to 2 cm in diameter; parallel bedding; overlain by fine-grained arenite; well sorted; small-scale, grouped trough-shaped, cross laminations and parallel laminations; light olive gray (5Y 6/1); moderate resistance to weathering . 1.5

80. Wacke, very fine-grained; well sorted; olive gray (5Y 4/1); fossils: Pelecypoda fragments rare 0.4

79. Conglomerate; clast up to 10 cm in diameter; very poorly sorted; large-scale, high angle, cross

SECTION 6 (cont.)

bedding; light olive gray (5Y 6/1); moderate resistance to weathering 1.4

78. Arkosic wacke, medium-grained; poorly sorted; grains subrounded; fining upward; dark yellowish orange (10 YR 6/6); moderate resistance to weathering; overlain by fine-grained quartz wacke; well sorted; light gray (N7); interbedded with very fine-grained sandy siltstone and silty claystone; slight resistance to weathering; fossils (transported): ?*Anodonta oregonensis* common; Ostracoda abundant 2.6

77. Arkosic wacke, medium-grained; poorly sorted; grains angular; equant; fining upward to very fine-grained wacke; dusky yellow (5Y 6/4); moderate resistance to weathering; overlain by clayey siltstone; light olive gray (5Y 5/2); slight resistance to weathering; base covered by rotational slump, debris flow, and soil . . . 1.1

76. Claystone; medium dark gray (N4); interbedded with very fine-grained sandy siltstone; dark yellowish orange (10YR 6/6); both weathered to medium gray (N5 to N6); slight resistance to weathering 2.1

75. Arkosic arenite, medium-grained; well sorted; grains very angular; subequant; large-scale, low angle, solitary, cross laminations; yellowish gray (5Y 7/2); overlain by arenite; pebbly; large-scale, low angle, cross bedding; overlain by conglomerate; channeled; fining upward; great resistance to weathering;

SECTION 6 (cont.)

fossils: bulbous stromatolites abundant with uncommon Pelecypoda fragments encrusted; ?_Anodonta oregonensis_ uncommon (transported) 4.2

74. Wacke, very fine-grained; small-scale, low angle, cross laminations; light olive gray (5Y 6/1); grading up to very fine-grained sandy siltstone; olive gray (5Y 4/1); overlain by very fine-grained wacke and arenite; small-scale, grouped, trough and planar, cross laminations; yellowish gray (5Y 7/2); moderate resistance to weathering (less than underlying unit) . 1.4

73. Arkosic arenite, very fine-grained; very well sorted; small-scale, low angle, trough-shaped, cross laminations; light olive gray (5Y 6/1); overlain by several pebbly stringers with coarse-grained sand fining upwards to very fine-grained wacke; large-scale channels rare; moderate resistance to weathering 2.4

72. Arkosic wacke; interbedded with silty claystone (medium gray (N5)) and very fine-grained wacke; well cemented; slight resistance to weathering; fossils: stromatolites up to 20 cm in diameter 0.7

71. Quartz arenite, fine-grained; very well sorted; grains subangular; subequant; large-scale, low angle, cross bedding; channels uncommon; overlain by pebbly conglomerate; very large-scale, low

SECTION 6 (cont.)

angle, cross bedding; yellowish gray (5Y 7/2); great resistance to weathering 2.4

70. Lithic wacke, very fine-grained; well sorted; small-scale, grouped, cross laminations; overlain by fine-grained arkosic wacke; fining up to sandy siltstone; overlain by arkosic wacke; entire unit light olive gray (5Y 6/1); slight resistance to weathering; fossils (transported): tubular stromatolites (3 mm in diameter) 3.0

69. Conglomerate; very poorly sorted; channels at base; very large-scale, high angle, pebbly, solitary, cross bedding near top; great resistance to weathering 2.1

68. Arkosic wacke, fine-grained; well sorted; small-scale, high angle, solitary, cross laminations over parallel laminations; moderate grayish yellow (5Y 7/4); overlain by conglomerate; poorly sorted; channels; two fining upward sequences (to wacke); moderate resistance to weathering 3.3

67. Quartz wacke, very fine-grained; poorly sorted; grains subrounded; bedded; parallel laminations at top; pale yellowish brown (10YR 6/2); slight resistance to weathering; fossils (in situ?): Spheriidae rare; Pelecypoda common 2.1

66. Arkosic wacke, medium-grained; well sorted; grains subangular; subelongate; large-scale, high angle,

SECTION 6 (cont.)

cross bedding; local channels with conglomerate; dusky yellow (5Y 6/4); moderate resistance to weathering 1.7

65. Claystone; overlain by very fine-grained wacke; coarsening upwards; overlain by fine-grained lithic wacke; large-scale, high angle, cross bedding; light olive gray (5Y 6/1); slight resistance to weathering 0.8

64. Arkosic arenite, medium-grained; well sorted; grains subrounded; fining upwards to fine-grained sandstone; thinly bedded; grayish orange (10YR 7/4); great resistance to weathering 0.6

63. Arkosic wacke, fine-grained; moderately well sorted; grains subrounded; subequant; increasing matrix upwards; small-scale, low angle, cross laminations; yellowish light olive gray (5Y 6/2); moderate resistance to weathering; fossils: charcoal fragments abundant; overlain by fine-grained arkosic wacke; moderately well sorted; grains angular; subequant; fining upwards to very fine-grained wacke; small-scale, low angle, cross laminations; slight resistance to weathering; fossils (transportated): Pelecypoda fragments abundant 1.4

62. Quartz wacke, fine-grained; poorly sorted; grains very angular; equant; light olive gray (5Y 6/1); grading upwards to very fine-grained sandy

SECTION 6 (cont.)

siltstone; medium light olive gray (5Y 5/1); slight resistance to weathering 0.3

61. Quartz wacke, fine-grained; moderately well sorted; grains subangular; subequant; light olive gray (5Y 6/1); great resistance to weathering; fossils: stromatolite fragments (less than 1 mm in diameter) abundant; tubular stromatolites uncommon; bulbous stromatolites (greater than 2 cm in diameter) rare; Ostracoda rare 0.5

60. Quartz wacke; very fine-grained; well sorted; small-scale, low angle, cross laminations; fining upwards to silty claystone; overlain by very fine-grained wacke; parallel bedding; light olive gray (5Y 6/1); slight resistance to weathering 1.0

59. Conglomerate; poorly sorted; channeled; very large-scale, high angle,cross bedding; fining upwards to medium-grained arenite; light olive gray (5Y 6/1); great resistance to weathering 2.3

58. Wacke, fine-grained; light olive gray (5Y 6/1); slight resistance to weathering; fossils: Ostracoda rare 0.1

57. Arkosic arenite, very fine-grained; well sorted; small-scale, high angle, cross laminations; yellowish light olive gray (5Y 6/2); moderate resistance to weathering; overlain by fine-grained arkosic arenite; very well sorted; grains angular; subelongate;

small-scale, low angle, cross laminations; dusky yellow (5Y 6/4); fossils (transported): Pelecypoda fragments rare; overlain by pebbly conglomerate; channeled; fining upwards to fine-grained arenite; overlain by beds of fine-grained arenite; well sorted; fining upwards; fossils (transported): Pelecypoda fragments rare 2.0

56. Lithic arenite, very fine-grained; very well sorted; light olive gray (5Y 6/1); grading up to medium-grained quartz arenite; well sorted; bedded, yellowish gray (5Y 8/1); great resistance to weathering; fossils (transported): Pelecypoda fragments rare 0.3

55. Wacke, very fine-grained; bedded; light olive gray (5Y 5/2); less matrix upward; light olive gray (5Y 6/1); slight resistance to weathering 0.6

54. Arkosic wacke, medium- and very fine-grained; bimodal sorting; grains rounded; equant; light olive gray (5Y 6/1); moderate resistance to weathering; fossils (transported): *Anodonta oregonensis* uncommon 0.4

53. Claystone, silty; well sorted; grades upward to very fine-grained arkosic wacke; parallel bedding; light olive gray (5Y 6/1); slight resistance to weathering . . 0.8

52. Quartz arenite, medium-grained; well sorted; grains angular; elongate to subequant; large-scale parallel bedding; dusky yellow (5Y 6/4); moderate resistance to weathering; overlain by fine-grained arkosic arenite; well sorted; grains angular; subequant;

SECTION 6 (cont.)

very large-scale, low angle, cross bedding; fining upwards; dusky yellow (5Y 6/4); moderate resistance to weathering (great resistance to weathering at base); fossils (transported): stromatolites (less than 1 cm in diameter); overlain by lithic arenite; well sorted; large-scale, high and low angle, cross bedding; interbedded with a conglomerate bed; fossils (in lithic arenite): charcoal common 6.8

51. Claystone, silty; micaceous; light olive gray (5Y 5/1); overlain by very fine-grained arkosic wacke; moderately well sorted; channels; overlain by silty claystone; medium light olive gray (5Y 5/1); slight resistance to weathering 0.5

50. Lithic wacke, fine-grained; moderately well sorted; grains subrounded; equant; small-scale, grouped, trough-shaped, cross laminations; interbeds of siltstone (1 cm thick) rare; dusky yellow (5Y 6/4); fossils: charcoal common; overlain by fine-grained arkosic arenite; very well sorted; grains subrounded; equant; large- and very large-scale, parallel bedding; grayish orange (10YR 7/4); overlain by coarse- and very coarse-grained arenite; channeled; several fining upward sequences; pebbly conglomerate; interbedded; mudstone rip up clasts; moderate resistance to weathering; fossils (transported): stromatolites rare (less than 6 cm in diameter 3.8

SECTION 6 (cont.)

49. Siltstone; light olive gray (5Y 5/1); overlain by very fine-grained arkosic wacke; very well sorted; moderate yellowish gray (5Y 7/4); overlain by medium-grained, sandy, silty, claystone; slight resistance to weathering . 0.8

48. Arkosic arenite, medium-grained; well sorted; grains subangular; equant; large-scale, low angle, solitary, cross bedding; interbeds of coarse- and very coarse-grained arenite and pebbly conglomerate; fining upwards; large-scale, parallel laminations near top; dusky yellow (5Y 6/4); great resistance to weathering 2.8

47. Lithic wacke, fine-grained; well sorted; grains subangular; equant; several stringers of coarse-grained arenite; fining upwards and repeated; dusky yellow (5Y 7/4); moderate resistance to weathering; fossils (transported?): Gastropoda (planispiral) rare 0.8

46. Claystone, silty; fossils: Ostracoda abundant; grades up to fine-grained arkosic wacke; well sorted; overlain by silty claystone; fossils: Ostracoda common; entire unit light olive gray (5Y 6/1); slight resistance to weathering 0.6

45. Arkosic wacke, fine-grained; poorly sorted; grains subangular; equant; light olive gray (5Y 6/1); moderate resistance to weathering; fossils (transported): stromatolites (tubular) common; ?Anodonta sp. rare . . . 0.7

44. Wacke, fine-grained; moderately well sorted; increasing matric upward; light olive gray (5Y 5/1); slight resistance to weathering 0.5

SECTION 6 (cont.)

43. Lithic arenite, fine-grained; moderately sorted; grains angular; equant; very large-scale, low angle, cross and parallel bedding; overlain by pebbly conglomerate; imbricated (paleocurrent S30E); fining upwards to wacke; entire unit grayish orange (10YR 7/4); great resistance to weathering (moderate resistance at top) 2.5

42. Arkosic wacke, very coarse-grained; pebbly; very poorly sorted; overlain by very fine-grained lithic wacke and siltstone; bedded; small-scale, high and low angle, cross laminations; light olive gray (5Y 5/1); slight resistance to weathering; fossils (transported): ?*Anodonta* sp. rare in upper siltstone 0.6

41. Arkosic wacke, very fine-grained; well sorted; grains subrounded; subequant; large-scale, low angle, cross bedding with channels containing pebbles; fining upwards to siltstone; overlain by channeled conglomerates and coarse-grained sandstone; parallel laminations; pale yellowish orange (10YR 8/4); moderate resistance to weathering 1.4

40. Siltstone; well sorted; claystone at base; light olive gray (5Y 5/1); slight resistance to weathering; fossils (*in situ*): *Anodonta oregonensis* rare; *Musculium lacustre* common; *M. transversum* common; ?*Stagnicola* sp. rare; ?*Planorbula* aff. *P. armigera* rare; Ostracoda rare 0.4

SECTION 6 (cont.)

39. Lithic arenite, very fine-grained; very well sorted; grains subangular; equant; small-scale, to large-scale, parallel laminations (uncommon small-scale, low angle, cross laminations); dusky yellow (5Y 6/4); moderate resistance to weathering 1.6

38. Siltstone; bedded; yellowish gray (5Y 7/2); overlain by very fine-grained arkosic wacke; well sorted; grains subangular; equant; moderate resistance to weathering; overlain by fine-grained quartz arenite; poorly sorted; grains angular; subequant; pebble beds; fining upwards; grayish yellow (5Y 8/4); great resistance to weathering 1.1

37. Arkosic wacke, medium-grained; moderately well sorted; small pebbles; grains subangular; subequant; large-scale, parallel bedding; yellowish orange (10YR 7/6); moderate resistance to weathering 1.0

36. Siltstone, clayey; interbedded with sandy, silty claystone; several gypsum beds; slight resistance to weathering 0.8

35. Arenite, very fine-grained; very well sorted; small-scale, high angle, trough-shaped, cross laminations; bedded; five gypsum layers; dark yellowish orange (10YR 6/6); moderate resistance to weathering; overlain by fine-grained

SECTION 6 (cont.)

quartz arenite; very well sorted; grains very angular; equant; small-scale, low angle, grouped, cross laminations with very large-scale parallel bedding; moderate yellowish gray (5Y 7/4); great resistance to weathering . . 1.2

34. Claystone, silty; grading upwards to clayey siltstone; gypsum layers; pale yellowish brown (10YR 6/2); slight resistance to weathering; fossils: Ostracoda rare. 0.7

33. Arkosic wacke, fine-grained; moderately sorted; grains angular; subeliptical; locally pebbles or very coarse-grained sand; fining upwards; very large-scale, low angle, cross bedding; dusky yellow (5Y 6/4); great resistance to weathering 2.6

32. Siltstone; light olive gray (5Y 5/2); slight resistance to weathering; overlain by very fine-grained arkosic wacke; well sorted; grayish orange (10YR 7/4); moderate resistance to weathering; overlain by fine-grained sandy siltstone; light olive gray (5Y 5/2); slight resistance to weathering 1.0

31. Arkosic wacke, fine-grained; well sorted; channels of very coarse-grained arenite near base; fining upwards; large-scale, high angle, cross bedding; grayish orange (10YR 7/4); moderate resistance to weathering 1.5

30. Siltstone, clayey; to silty claystone; bedded; greenish gray (5GY 6/1); slight resistance to

SECTION 6 (cont.)

weathering; fossils: ?*Anodonta oregonensis* rare; *Limnocythere* sp. rare; *Cyprinutus* aff. *C. salinus* rare 0.8

29. Arkosic wacke, fine-grained; poorly sorted; grains angular; elongate; pale blue (5B 5/1); moderate resistance to weathering 0.5

28. Arkosic wacke, fine-grained; poorly sorted; grains rounded; equant; large- and very large-scale, low angle, cross and parallel bedding near base; overlain by very large-scale, pebbly parallel beds; overlain by very fine-grained sandy siltstone and wacke; dusky yellow (5Y 6/4); moderate resistance to weathering 1.3

27. Arkosic wacke, very fine grained; moderately well sorted; grains subangular; equant; small-scale, low angle, cross laminations at base, up to high angle, trough-shaped, cross laminations; dusky yellow (5Y 6/4); overlain by very fine-grained sandy siltstone; medium dark gray (N4); slight resistance to weathering . 0.4

26. Quartz arenite, very coarse-grained; poorly sorted; pebbly; grains rounded; grayish orange (10YR 7/4); moderate resistance to weathering; overlain by very fine-grained lithic arenite; very well sorted; small-scale, high angle, cross laminations; light gray (N7); overlain by fine-grained arkosic wacke; moderately well sorted; grains subangular; equant; large-scale, parallel

SECTION 6 (cont.)

laminations; dark yellowish orange (10YR 6/6); moderate resistance to weathering; overlain by fine-grained arkosic wacke; moderately well sorted; grains subangular; equant; rip up clasts; large- and very large-scale, low angle, cross bedding; channeled conglomerates; moderate resistance to weathering 1.9

25. Siltstone, sandy; moderately sorted; light olive gray (5Y 5/2); slight resistance to weathering; fossils: *Anodonta oregonensis* rare 1.2

24. Arkosic wacke; medium-grained; moderately well sorted; grains subrounded; equant; increasing matrix upwards; dusky yellow (5Y 6/4); moderate resistance to weathering . . 1.4

23. Arkosic wacke, very fine-grained; moderately well sorted; light olive gray (5Y 5/2); slight resistance to weathering 5.0

22. Arkosic arenite, fine-grained; moderately sorted; grains subrounded; subequant; bedded; fining upward sequence from coarse- to very fine-grained; channels locally; yellowish light olive brown (5Y 6/6); moderate resistance to weathering 1.6

21. Siltstone; medium dark gray (N4); fossils: charcoal rare; overlain by fine-grained quartz arenite; moderately well sorted; grains subangular; subequant; fining upwards; yellowish gray (5Y 7/2); overlain by fine-grained, sandy siltstone; medium light gray (N6); slight resistance to weathering 0.6

SECTION 6 (cont.)

20. Arkosic wacke, fine-grained; moderately well sorted; grains subrounded; subequant; grading upwards to well sorted; moderate dusky yellow (5Y 7/4); moderate resistance to weathering 1.1

19. Quartz arenite, fine-grained; moderately well sorted; grains very angular; elongate; light olive gray (5Y 6/1); moderate resistance to weathering 0.9

18. Claystone, silty; moderate greenish gray (5GY 5/1); slight resistance to weathering 0.7

17. Lithic wacke, very fine-grained; moderately well sorted; grains angular; equant; small-scale, trough-shaped cross bedding rare; moderate yellowish orange (10YR 7/6); moderate resistance to weathering; fossils (transported): stromatolites 0.7

16. Claystone; dark greenish black (5GY 5/1); fossils (transported): Spheriidae common; Ostracoda rare; <u>Merychippus</u> aff. <u>M.</u> <u>sumani</u> rare (in float) 0.5

15. Arkosic arenite, medium-grained; well sorted; grains angular; equant; grayish orange (10YR 7/4); moderate resistance to weathering 0.4

14. Siltstone, sandy; to fine-grained arkosic wacke; grades up to medium-grained arkosic wacke; well sorted; grains subangular; equant; overlain by very fine-grained sandy siltstone; entire unit grayish yellow (5Y 8/4); moderate resistance to weathering 0.9

SECTION 6 (cont.)

13. Arkosic wacke, medium-grained; moderately sorted; grains subangular; subeliptical; fining upwards to fine-grained arenite; well sorted; grayish orange (10YR 7/4); overlain by medium-grained arkosic wacke; poorly sorted; grains subrounded; subequant; pebbly; several fining upward sequences; dark yellowish orange (10YR 6/6); moderate resistance to weathering . . 1.4

12. Arkosic arenite, medium-grained; well sorted; grains subangular; subequant; grayish orange (10YR 7/4); interbedded with fine-grained sandy siltstone; light olive gray (5Y 5/1); slight resistance to weathering; fossils (in lowermost arenite): Anodonta oregonensis abundant; Musculium lacustre rare; M. transversum rare . . . 1.8

11. Arkosic wacke, very coarse-grained; poorly sorted (bimodal); grains subeliptical; very large-scale, low angle, cross bedding; bedded pebbles; dark grayish orange (10YR 7/6); moderate resistance to weathering 1.6

10. Siltstone, sandy; moderately well sorted; bedded; light olive gray (5Y 6/1); slight resistance to weathering; fossils (transported): Anodonta oregonensis abundant; Musculium transversum rare; ?Stagnicola sp. uncommon; Ostracoda uncommon; fish rare 2.3

9. Arkosic wacke, fine-grained; moderately sorted; grains subangular; subequant; large-scale,

SECTION 6 (cont.)

parallel laminations; grayish orange (10YR 7/4); moderate resistance to weathering 1.0

8. Siltstone, clayey; grading up to very fine-grained arkosic wacke; moderately sorted; small-scale, low angle, trough-shaped, cross laminations; light olive gray (5Y 6/1); slight resistance to weathering 0.6

7. Quartz arenite, coarse-grained; poorly sorted; grains angular; subequant; pebbly; very large-scale, high angle, cross bedding; overlain by coarse-grained quartz arenite; moderately sorted; large-scale, parallel laminations; grayish orange (10YR 7/4); moderate resistance to weathering 1.8

6. Siltstone, sandy; olive black (5Y 2/1); overlain by very fine-grained arkosic wacke; parallel bedding; olive black (5Y 2/2); slight resistance to weathering 3.5

5. Conglomerate, pebbly; bedded; dusky yellow (5Y 6/4); overlain by medium-grained arkosic wacke; poorly sorted; grains subangular; subelongate; great resistance to weathering; fossils: stromatolites uncommon; Anodonta oregonensis common 4.9

4. Covered with soil and colluvium

3. Arenite, medium-grained; fining upwards; moderate resistance to weathering 3.8

SECTION 6 (cont.)

2. Arkosic wacke, fine-grained; poorly sorted; grains subangular; equant; light olive gray (5Y 6/1); slight resistance to weathering 1.2

1. Conglomerate; fining upwards to medium-grained arkosic wacke; poorly sorted; grains subangular; equant; large-scale, low angle, pebble, cross bedding in lower section; increasing matrix upwards; moderate grayish orange (10YR 6/4); great resistance to weathering 5.2

Total thickness 143.3

SECTION 7

Section 7 (SE¼SE¼NW¼ sec. 6, T. 6 N., R. 17 W.) is about 61 m south of benchmark 3514 on the east side of the Old Ridge Route. Most of the section is covered with colluvium. Accession number: 5715; Figure 9 (columnar section).

Top of section Unit	Thickness (metres)
2. Arkosic arenite, medium-grained; pebbly; poorly sorted; grains very angular; subelongate; large-scale, parallel bedding; grayish orange (10YR 7/4); moderate resistance to weathering	3.3
1. Lithic wacke, very fine-grained; small scale, parallel laminations; light olive gray (5Y 6/1); fossils: plant fragments; covered and overlain by siltstone; interbedded with claystone; pale yellowish brown (10YR 6/2); slight resistance to weathering; fossils: *Musculium lacustre* abundant; *M. transversum* abundant; ?*Stagnicola* sp. uncommon	1.8
Total thickness	5.1

SECTION 8

Section 8 is located north of benchmark 3514, on the north side of the unmaintained dirt road that intersects the Old Ridge Route. The base of the section (NE¼SE¼NW¼ sec. 6, T. 6 N., R. 17 W.) is 30 m stratigraphically above the top of section 7 and is on the west side of the Old Ridge Route. Accession numbers: 5716-5717; Figure 9 (columnar section).

Top of section Unit		Thickness (metres)
10.	Wacke, very fine-grained; interbedded with silty claystone; pale yellow (5Y 6/2); slight resistance to weathering; fossils: Ostracoda rare	5.0
9.	Arkosic wacke, medium-grained; large-scale, low angle, cross laminations; concretions up to 50 cm in diameter; grayish orange (10YR 7/4); moderate resistance to weathering (great resistance near concretions)	5.5
8.	Wacke, medium-grained; poorly sorted; grains angular; equant; fining upwards to siltstone; moderate pale yellowish brown (10YR 5/2); slight resistance to weathering	0.5
7.	Arkosic wacke, very fine-grained; well sorted; grains subrounded; large- and very large-scale soft sediment deformation; conglomerate locally; yellowish gray (5Y 7/2) to moderate pale orange brown (10YR 6/2); moderate resistance to weathering (friable at surface)	2.0

SECTION 8 (cont.)

6.	Wacke, very fine-grained; very well sorted; interbedded with fine-grained lithic wacke; grayish orange (10YR 7/4); moderate resistance to weathering . .	0.8
5.	Claystone, silty; moderate yellowish brown (10YR 5/4); interbedded with very fine-grained wacke; grayish orange (10YR 7/4); slight resistance to weathering; fossils: plants abundant; _Musculium lacustre_ common; _M. transversum_ common; ?_Planorbula_ aff. _P. armigera_ uncommon; Ostracoda abundant.	0.6
4.	Arkosic arenite, fine-grained; very well sorted; small-scale, low angle, cross laminations; increasing matrix upwards; light olive gray (5Y 6/1); moderate resistance to weathering	0.4
3.	Wacke, very fine-grained; bedded; light olive gray (5Y 6/1); slight resistance to weathering; fossils (_in situ_): _Musculium transversum_ abundant; Ostracoda rare	0.4
2.	Arkosic arenite; medium-grained; very well sorted; grains subangular; equant; large-scale, cross bedding; light gray (N7) to dark yellowish orange (10YR 6/6) on weathered surface; moderate resistance to weathering; fossils: stromatolites (tubular, less than 2 cm in diameter)	0.8
1.	Arkosic wacke, medium-grained; moderately sorted; grains subangular; subelongate; large-scale, high	

SECTION 8 (cont.)

angle, cross bedding; interbeds of pebbly conglomerate; grayish orange (10YR 7/4); great resistance to weathering 3.2

Total thickness 19.2

SECTION 9

Section 9 is on the west side of the Old Ridge Route. The base of the section (SW¼NE¼NW¼ sec. 6, T. 6 N., R. 17 W.) begins about 200 m north of benchmark 3514 and extends about 50 m northwest. Accession number: 5718; Figure 9 (columnar section).

Top of section

Unit		Thickness (metres)
12.	Wacke, very fine-grained; light olive gray (5Y 6/1); slight resistance to weathering; fossils: Ostracoda common	1.0
11.	Conglomerate, pebbly; very large-scale, parallel bedding; several fining upward sequences; grayish orange (10YR 7/4); great resistance to weathering .	2.8
10.	Wacke, very fine-grained; light olive gray (5Y 6/1); slight resistance to weathering; fossils: Ostracoda abundant; overlain by medium-grained arkosic wacke; well sorted; grains subangular; equant; large-scale, low angle, cross bedding; grayish orange (10YR 7/4); moderate resistance to weathering; overlain by same as base; fossils: plants rare; Ostracoda rare	1.8
9.	Arkosic arenite, very fine-grained; well sorted; grains angular; equant; small-scale, high angle, grouped and solitary, cross laminations; grayish orange (10YR 7/4); great resistance to weathering; fossils: stromatolites (less than 1 cm in diameter) common; Ostracoda abundant	2.0

SECTION 9 (cont.)

8. Arkosic wacke, fine-grained; moderately well sorted; grains subangular; equant; large-scale, low angle, cross bedding; grayish orange (10YR 7/4); moderate resistance to weathering; normal fault through top . . . 6.0

7. Arkosic arenite, fine-grained; very well sorted; grains subangular; equant; small- and large-scale, low angle, cross bedding; grayish orange (10YR 7/4); great resistance to weathering 1.8

6. Siltstone, sandy; interbedded with claystone; light olive gray (5Y 5/2); slight resistance to weathering . . 0.7

5. Wacke, very fine-grained; interbedded with very fine-grained arkosic arenite; small-scale, low angle, trough-shaped, cross laminations; pale grayish orange (10YR 7/2); moderate resistance to weathering . . 1.3

4. Claystone, silty; and less abundant clayey siltstone; bedded; light olive gray (5Y 5/2); slight resistance to weathering; fossils: stromatolites rare; plants rare; Musculium transversum rare; ?Stagnicola sp. rare; ?Planorbula aff. P. armigera rare; Ostracoda rare 2.3

3. Arenite, very fine-grained, well sorted; small-scale, low angle, trough-shaped, cross laminations; fining upwards to wacke; light olive gray (5Y 6/1); moderate resistance to weathering; fossils: stromatolites (fragments) abundant; stromatolite colonies uncommon; Ostracoda common 1.9

SECTION 9 (cont.)

2. Claystone, silty; interbedded with very fine-grained wacke; dusky yellow (5Y 6/4); slight resistance to weathering 0.8

1. Wacke, very fine-grained; well sorted; increasing matrix upwards; small-scale, light olive gray (5Y 6/1); moderate resistance to weathering; fossils: stromatolite fragments (2 mm in diameter) common; Ostracoda abundant 2.1

Total thickness 24.5

SECTION 10

Section 10 is about 490 m northwest of benchmark 3514 on the west side of the Old Ridge Route. The base of the section (NE¼NW¼NW¼ sec. 6, T. 6 N., R. 17 W.) begins about 400 m northwest of benchmark 3514 and extends about 300 m northwest along the Old Ridge Route. Accession numbers: 5719-5725; Figures 9-10 (columnar sections).

Top of section Unit		Thickness (metres)
23.	Arenite, fine-grained; interbedded with very fine-grained wacke; small-scale, trough-shaped, cross laminations; moderate resistance to weathering; fossils (transported?): plants uncommon; *Musculium transversum* common; *Pisidium* (*Cyclocalyx*) *nitidum* abundant; *Fontelicella* aff. *F.* (*F.*) *truckeensis* abundant; ?*Stagnicola* sp. uncommon; ?*Planorbula* aff. *P. armigera* common; Ostracoda abundant	6.7
22.	Arkosic arenite, fine-grained; very well sorted; grains very angular; subequant; large-scale, low angle, cross laminations; several fining upward cycles; dusky yellow (5Y 6/4); great resistance to weathering	2.1
21.	Arkosic arenite; fine-grained; well sorted; large-scale, low angle, cross bedding; dusky yellow (5Y 6/4); great resistance to weathering	1.6
20.	Wacke, very fine-grained; well sorted; small-scale, parallel bedding; light olive gray (5Y 6/1); moderate	

SECTION 10 (cont.)

resistance to weathering; fossils (transported): stromatolite fragments (less than 1 cm in diameter) rare 1.1

19. Conglomerate; very poorly sorted; pebbly; large-scale, low angle, cross bedding; overlain by medium-grained arkosic arenite; well sorted; grains angular; equant; large-scale, high angle, cross bedding; grading upwards to large- and small-scale, low angle, cross bedding; rip up clasts rare; increasing matrix upwards; entire unit dusky yellow (5Y 6/4); great resistance to weathering 3.0

18. Wacke, fine-grained; well sorted; fining upwards to very fine-grained wacke and siltstone; light olive gray (5Y 6/1); slight resistance to weathering . . 1.0

17. Arkosic arenite, fine-grained; well sorted; grains angular; equant; large-scale, trough-shaped, cross bedding; overlain by very large- and large-scale, low angle, planar, cross bedding; dusky yellow (5Y 6/4); great resistance to weathering 5.0

16. Arkosic arenite, medium-grained; very well sorted; great resistance to weathering 0.2

15. Arkosic arenite, very coarse-grained; pebbly at base; medium-grained in upper portion; poorly sorted; bedded; fewer pebble beds upwards; large-scale, grouped, low angle, cross bedding; dusky

SECTION 10 (cont.)

yellow (5Y 6/4); great resistance to weathering 2.2

14. Arkosic arenite; fine-grained; very well sorted; grains subangular; equant; moderate resistance to weathering; interbedded with very fine-grained wacke; small-scale, low angle, grouped, trough-shaped, cross bedding; moderate olive brown (5Y 5/4); slight resistance to weathering 1.4

13. Arenite, very fine-grained; very well sorted; concretions uncommon in lower 50 cm; dusky yellow (5Y 6/4); moderate resistance to weathering 0.8

12. Arkosic arenite, medium-grained; poorly sorted; grains subangular; equant; conglomerate channels; yellowish gray (5Y 7/2); overlain by coarse-grained arkosic wacke; very poorly sorted; light olive gray (5Y 6/1); moderate resistance to weathering 1.8

11. Arkosic wacke, very fine-grained; poorly sorted; grains subrounded; subelongate; light olive gray (5Y 6/1); slight resistance to weathering; fossils (transported): *Musculium lacustre* rare; *M. transversum* common; ?*Stagnicola* sp. common; ?*Planorbula* aff. *P. armigera* common; Ostracoda rare; fish rare 7.0

10. Arkosic arenite, medium-grained; moderately well sorted; grains subrounded; equant; very large-scale, low and high angle, cross bedding; several

SECTION 10 (cont.)

pebbly conglomerate beds; grayish orange (10YR 7/4); great resistance to weathering 8.0

9. Arkosic arenite, fine-grained; very well sorted; grains angular; equant; grayish orange (10YR 7/4); fining upwards into very fine-grained wacke; light olive gray (5Y 6/1); entire sequence repeated; small-scale, low angle, trough-shaped and planar, grouped, cross laminations 2.0

8. Claystone, silty and clayey siltstone; bedded; light olive gray (5Y 5/2); slight resistance to weathering; fossils (transported?): plants rare; *Anodonta oregonensis* rare; *Musculium transversum* rare; ?*Pisidium* (*Cyclocalyx*) *nitidum* rare; ?*Stagnicola* sp. abundant; ?*Planorbula* aff. *P. armigera* uncommon; Gastropoda fragments rare; Ostracoda rare 1.4

7. Wacke, very fine-grained; light olive gray (5Y 6/1); interbedded with very fine-grained arenite; small-scale, low angle, trough-shaped, cross bedding; moderately pale yellowish brown (10YR 7/2); slight resistance to weathering; fossils: Ostracoda rare; grading upwards to fine-grained arkosic arenite; well sorted; grains subangular; equant; small-scale, low angle, trough-shaped, cross bedding up to large-scale, low angle, planar, cross bedding; coarsening upwards with very large-scale, low angle solitary cross bedding; grayish orange (10YR 7/4); great resistance to weathering . 7.3

SECTION 10 (cont.)

6. Claystone, silty; interbedded with clayey siltstone; olive gray (5Y 4/1); coarsening upwards to very fine-grained wacke; light olive gray (5Y 6/1); slight resistance to weathering; fossils (*in situ*): plants abundant; *Musculium lacustre* common; *M. transversum* common; *Pisidium (Cyclocalyx) nitidum* common; ?*Stagnicola* sp. abundant; ?*Planorbula* aff. *P. armigera* common; Ostracoda uncommon 2.5

5. Conglomerate; poorly sorted; large-scale, low angle, and parallel bedding; light olive gray (5Y 6/1); great resistance to weathering; overlain by very fine-grained arkosic wacke; well sorted; grains subangular; equant; interbedded with minor beds of very fine-grained lithic wacke; small-scale, low angle and high angle, trough and planar, cross laminations and with large-scale, low angle, cross bedding; dusky yellow (5Y 6/4); fossils (transported): stromatolites (up to 10 cm in diameter) common; ?*Stagnicola* sp. rare . . 9.1

4. Wacke, very fine-grained; grains subangular; equant; moderately sorted; grading upwards to very fine-grained wacke; very well sorted; large-scale, low angle, cross bedding; moderate grayish yellow (5Y 7/4); slight resistance to weathering; fossils (transported): ?*Stagnicola* sp. 4.8

3. Conglomerate, pebbly arenaceous; arkosic; very large-scale, low angle, grouped, planar, cross

SECTION 10 (cont.)

bedding; channels rare; pale yellowish orange (10YR 8/6); great resistance to weathering; fossils (transported): plants rare; ?*Stagnicola* sp. common (in upper 5 cm) 4.1

2. Claystone, silty; and clayey siltstone; bedded; light olive gray (5Y 5/2); slight resistance to weathering; fossils (*in situ*): plants abundant; *Anodonta oregonensis* rare; *Musculium transversum* rare; ?*Stagnicola* sp. abundant; Gastropoda fragments uncommon; overlain by very fine-grained arkosic wacke; bedded; light olive gray (5Y 6/1); slight resistance to weathering; fossils: plants abundant 2.0

1. Arkosic arenite, very fine-grained; well sorted; grains subangular; subequant; large- and very large-scale, low angle, cross bedding; small-scale, high angle, grouped, trough-shaped, cross laminations; interbedded with three very fine-grained wackes; grayish orange (10YR 7/4); moderate resistance to weathering; fossils (transported): *Musculium transversum* rare; ?*Stagnicola* sp. abundant; ?*Planorbula* aff. *P. armigera* rare; Gastropoda uncommon 3.8

Total thickness 78.9

SECTION 11

Section 11 is on the west side of the Old Ridge Route about 450 m due south of benchmark 3616. The base of the measured section (SW¼SW¼NW¼ sec. 31, T. 7 N., R. 17 W.) is at the south end of the first outcrop, south of the Forest Service gate, and to the west near the ARCO pipeline. The section extends about 100 m northwest along the western side of the Old Ridge Route. Accession numbers: 5726-5729; Figure 10 (columnar section).

Top of section Unit	Thickness (metres)
12. Claystone, silty and clayey siltstone; medium gray (N5); slight resistance to weathering; (mostly covered); fossils: Ostracoda rare	2.0
11. Conglomerate, pebbly; poorly sorted; mudstone rip up clasts; very large-scale, high angle, cross bedding; fining upward to fine-grained arkosic arenite; soft sediment deformation; entire unit is moderate grayish orange (10YR 6/4); moderate resistance to weathering	2.8
10. Arenite, very fine-grained; well sorted; small-scale, low and high angle, grouped, trough-shaped and planar, cross bedding; overlain by silty claystone; yellowish gray (5Y 7/2); moderate resistance to weathering	2.1
9. Wacke, very fine-grained; massive bedding; light olive gray (5Y 6/1); great resistance to weathering; fossils (transported): plants uncommon;	

SECTION 11 (cont.)

?*Stagnicola* sp. rare; ?*Planorbula* aff. *P. armigera* abundant; fish (Teleostei) rare; Vertebrata rare 0.2

8. Arenite, very fine-grained; well sorted; pebbly conglomerate at base; large-scale, low angle, cross bedding; several fining upward sequences; light olive gray (5Y 6/1); moderate resistance to weathering 1.2

7. Wacke, fine-grained; poorly sorted, massive bedding; light olive gray (5Y 6/1); great resistance to weathering; fossils (transported): ?*Planorbula* aff. *P. armigera* abundant 0.2

6. Conglomerate, pebbly; poorly sorted; bedded, light olive gray (5Y 6/1); moderate resistance to weathering 0.4

5. Wacke, very fine-grained; moderately sorted; light olive gray (5Y 6/1); grading upwards to very fine-grained arenite; small-scale, low angle, cross laminations; dusky yellow (5Y 6/4); slight resistance to weathering; fossils (transported): plants uncommon; *Musculium transversum* rare; Spheriidae rare; ?*Stagnicola* sp. common; ?*Planorbula* aff. *P. armigera* abundant; Ostracoda uncommon 1.0

4. Arenite, medium-grained; well sorted; grains subrounded; equant; light olive gray (5Y 6/1); great resistance to weathering 0.2

SECTION 11 (cont.)

3.	Conglomerate, pebbly; poorly sorted; very angular sand grains; large-scale, low and high angle, grouped, cross bedding; dusky yellow (5Y 6/4); moderate resistance to weathering	1.6
2.	Arkosic wacke; fine-grained; poorly sorted; grains subrounded; equant; small-scale, low angle, grouped, trough-shaped, cross laminations; dusky yellow (5Y 6/4); slight resistance to weathering	1.6
1.	Conglomerate, pebbly; very poorly sorted; parallel bedding; dusky yellow (5Y 6/4); slight resistance to weathering	2.4
Total thickness	. . . .	15.7

SECTION 12

Section 12 is on the Old Ridge Route about 0.8 km north of Reservoir Summit. The base of the section (SW¼SW¼NW¼ sec. 30, T. 7 N., R. 17 W.) begins on the west side of the road directly across from benchmark 3708 (benchmark 3708 is located in the power line foundation) and extends northward for about 200 m. Accession numbers: 5730-5732; Figure 10 (columnar section).

Top of section Unit	Thickness (metres)
4. Wacke, very fine-grained; with fine-grained wacke and siltstone at base; slight resistance to weathering; fossils: plants uncommon; ?*Planorbula* aff. *P. armigera* abundant; *Candona* spp. common; ?*Cyprideis* sp. common; *Darwinula* sp. common; *Limnocythere* sp. common; *L. ornata* common; *Cyprinotus* aff. *C. salinus* common . .	2.0
3. Arenite, very fine-grained; very well sorted; light olive gray (5Y 6/1); great resistance to weathering; fossils: plants uncommon; ?*Musculium transversum*; ?*Stagnicola* sp. rare; *Planorbula* aff. *P. armigera* abundant; *Candona* sp. common; *Darwinula* sp. common; *Limnocythere* sp. common; *L.* aff. *L. ornata* common; *Cyprinotus* aff. *C. salinus* common	0.2
2. Quartz arenite, fine-grained; very well sorted; large-scale, parallel and low angle, cross bedding; mudstone rip up clasts rare; uncommon pebbly conglomerate; dusky yellow (5Y 6/4); moderate resistance to weathering	7.2

SECTION 12 (cont.)

1. Conglomerate, pebbly; poorly sorted; channels rare; very large-scale, low angle, cross bedding; fining upwards to medium-grained arkosic arenite; poorly sorted; grains subrounded; subequant; large- and very large-scale, low angle, cross bedding; yellowish gray (5Y 7/2); great resistance to weathering; fossils: stromatolites abundant; ?*Cyprideis* sp. abundant 7.5

Total thickness 16.9

SECTION 13

Section 13 is about 400 m north of benchmark 3572 on the Old Ridge Route. The base of the section (NE¼SE¼SE¼ sec. 24, T. 7 N., R. 18 W.) begins on the west side of the road at the axis of a large sharp curve in the road and extends southward about 50 m. Accession numbers: 5733-5735; Figure 10 (columnar section).

Top of section Unit	Thickness (metres)
10. Conglomerate, fining upwards to arenite; well sorted, massive bedding; great resistance to weathering	2.8
9. Arkosic arenite, medium-grained; well sorted; grains very angular; equant; large-scale, low angle, cross laminations; fining upward cycles; mudstone rip up clasts rare; dusky yellow (5Y 6/4); great resistance to weathering; fossils (transported): ?<u>Planorbula</u> aff. <u>P</u>. <u>armigera</u> abundant	9.0
8. Wacke, very fine-grained, interbedded with very fine-grained arenite and fine-grained wacke; small-scale, low angle, trough-shaped, cross laminations uncommon; light olive gray (5Y 6/1-5Y 5/2); slight resistance to weathering; fossils (transported): base--plants uncommon; <u>Pisidium</u> (<u>Cyclocalyx</u>) <u>nitidum</u> rare; ?<u>Planorbula</u> aff. <u>P</u>. <u>armigera</u> common; <u>Cyprideis</u> <u>beaconensis</u>	

SECTION 13 (cont.)

common; Candona spp. common; ?Cyprideis sp. common; Darwinula sp. common; Limnocythere aff. L. ornata common; Cyprinotus aff. C. salinus common; Top--?Planorbula aff. P. armigera rare; Gastropoda common . . . 4.2

7. Quartz arenite, medium-grained; grains very angular; subelongate; pebbly stringers; fining upward sequences; dusky yellow (5Y 6/4); moderate resistance to weathering; overlain by same arenite; very well sorted; large-scale, low angle, grouped, planar, cross bedding; great resistance to weathering 2.8

6. Arkosic arenite, fine-grained; grains angular; subequant; large-scale, low angle, planar, cross bedding with large-scale, grouped, trough-shaped, cross bedding; fossils: stromatolites abundant 1.2

5. Wacke, fine-grained; moderately well sorted; interbedded with fine-grained arenite; parallel bedding and small-scale, low angle, trough-shaped, cross laminations; light olive gray (5Y 5/2); slight resistance to weathering 1.0

4. Arkosic arenite, medium-grained; poorly sorted; grains very angular; equant; large-scale, low angle, cross bedding; channels; discontinuous stringers of pebble conglomerate; small-scale, low angle, grouped, trough-shaped, cross laminations; interbedded with lithic wacke; pale yellow-brown (10YR 6/2); moderate resistance to weathering . . . 1.9

SECTION 13 (cont.)

3. Arkosic wacke, moderately well sorted; grains subangular; equant; light olive brown (5Y 5/6); great resistance to weathering; fossils: stromatolites rare . . . 0.3

2. Lithic wacke, fine-grained; well sorted; parallel bedding; small-scale, low angle, trough-shaped, cross laminations; slight resistance to weathering 0.8

1. Conglomerate, pebbly; poorly sorted; large-scale, low angle, cross bedding; dark yellowish orange (10YR 6/6); moderate resistance to weathering 1.9

Total thickness 25.9

SECTION 14

Section 14 is along the Old Ridge Route just south of Halfway Inn. The base of the section (SE¼NW¼NW¼ sec. 19, T. 7 N., R. 17 W.) begins under the westernmost power line on the north side of the road and extends east about 100 m (ends before northern road to Halfway Inn). Accession numbers: 5736-5737; Figure 10 (columnar section).

Top of section Unit	Thickness (metres)
3. Arenite, medium-grained; well sorted; very light gray (N8); slight resistance to weathering; fossils: Ostracoda	2.0
2. Wacke, fine-grained; and very fine-grained wacke; interbedded near base with siltstone and less with claystone; light dusky yellow (5Y 6/2); slight resistance to weathering; fossils (transported): lowest horizon--*Anodonta oregonensis* common; *Musculium lacustre* uncommon; *Pisidium (Cyclocalyx) nitidum* rare; ?*Stagnicola* sp. common; *Candona* spp. common; ?*Cyprideis* sp. common; ?*Cythermorpha* sp. common; *Darwinula* sp. common; *Limnocythere* aff. *L. ornata* common; *Cyprinotus* aff. *C. salinus* common; Second horizon--?*Planorbula* aff. *P. armigera* rare; overlain by same wacke; small-scale, low and high angle, trough-shaped, grouped, cross laminations . . .	10.0
1. Conglomerate, pebbly; very poorly sorted; channels; fining upward sequences; large-scale, low angle,	

SECTION 14 (cont.)

cross bedding; wacke rip up clasts; light olive gray (5Y 6/1); great resistance to weathering 10.4

Total thickness 22.4

SECTION 15

Section 15 is about 400 m north of Halfway Inn along the Old Ridge Route. The base of the section (SE¼NW¼NW¼ sec. 19, T. 7 N., R. 17 W.) begins in a flat-bottomed ravine on the south side of the road and extends about 300 m southwest. Accession number: 5738; Figure 11 (columnar section).

Top of section Unit	Thickness (metres)
4. Siltstone interbedded with very fine-grained wacke, small-scale, low angle, cross laminations; light olive gray (5Y 5/2); slight resistance to weathering; fossils (transported): plants uncommon; charcoal common; *Anodonta oregonensis* abundant; ?*Stagnicola* sp. uncommon; ?*Planorbula* aff. *P. armigera* abundant; *Candona* spp. abundant; ?*Cyprideis* sp. abundant; *Cytheromorpha* sp.? abundant; *Darwinula* sp. abundant; *Limnocythere* aff. *L. ornata* abundant; *Cyprinotus* aff. *C. salinus* abundant	1.2
3. Conglomerate; poorly sorted; large-scale channels; fining upwards to medium-grained quartz arenite; moderately sorted; grains very angular; elongate; large-scale, low angle, cross bedding; several faults; scattered pebbles; light olive gray (5Y 6/1); slight resistance to weathering	4.0
2. Wacke, fine-grained; decreasing matrix upwards; large-scale, low angle, cross bedding; light dusky yellow (5Y 6/2); slight resistance to	

SECTION 15 (cont.)

weathering at base; up to moderate resistance at top; fossils: plants abundant 2.2

1. Conglomerate, pebbly; fining upward to medium-grained quartz arenite; moderately well sorted; grains angular; subequant; large-scale, low angle, cross bedding; light olive gray (5Y 6/1); moderate resistance to weathering . 1.7

Total thickness 9.1

SECTION 16

Section 16 is along the Old Ridge Route about 600 m northeast of Halfway Inn. The base of the section (NW¼NE¼SW¼ sec. 19, T. 7 N., R. 17 W.) begins at the widest portion of the road in the large curve (southwest side of road) near the base of a slump and extends about 100 m northwestward. Accession number: 5739; Figure 11 (columnar section).

Top of section Unit	Thickness (metres)
9. Conglomerate; fining upwards to medium-grained quartz arenite; large-scale, low angle, cross bedding; great resistance to weathering	4.0
8. Wacke, fine-grained; interbedded with very fine-grained wacke and medium-grained wacke and medium-grained quartz arenite (arenite erodes underlying wacke); moderate resistance to weathering; fossils: stromatolites	11.0
7. Quartz arenite, medium-grained; moderate resistance to weathering	1.4
6. Wacke, fine-grained; large-scale, low angle, cross bedding; light dusky yellow (5Y 6/2); slight resistance to weathering	1.2
5. Conglomerate, pebbly; mudstone rip up clasts rare; grades upwards to coarse-grained quartz arenite; moderately well sorted; grains very angular; elongate; very large-scale, low angle, cross bedding; light olive gray (5Y 6/1); great	

SECTION 16 (cont.)

resistance to weathering; fossils (transported): stromatolites (less than 2 cm in diameter) abundant; ?*Anodonta oregonensis* common 12.0

4. Siltstone; interbedded with very fine-grained wacke and uncommonly with fine-grained arenite; light olive gray (5Y 5/2); slight resistance to weathering; fossils (*in situ*): plants uncommon; *Anodonta oregonensis* abundant; ?*Stagnicola* sp. uncommon; ?*Planorbula* aff. *P. armigera* abundant; Ostracoda abundant 2.8

3. Conglomerate; pebbly; large-scale, low angle, cross bedding; fining upwards to medium-grained arkosic arenite; very poorly sorted; grains angular; light olive gray (5Y 6/1); moderate resistance to weathering . 3.2

2. Wacke, fine-grained; small- and large-scale, low angle, cross bedding; yellowish light olive gray (5Y 6/2); slight resistance to weathering; fossils: plants abundant 1.9

1. Conglomerate, pebbly; fining upwards to medium-grained arkosic arenite; poorly sorted; grains angular; subequant; large-scale, low angle, cross bedding; light olive gray (5Y 6/1); moderate resistance to weathering 4.0

Total thickness 41.5

SECTION 17

Section 17 is about 700 m southwest of benchmark 3775 along the Old Ridge Route. The base of the section (NW¼NW¼SE¼ sec. 18, T. 7 N., R. 17 W.) begins 40 m east of the Edison access road (to the north) on the south side of the road, and extends about 200 m northeastward. Accession number: 5740; Figure 11 (columnar section).

Top of section Unit	Thickness (metres)
6. Conglomerate, pebbly; very poorly sorted; channels; moderate grayish yellow (5Y 7/4); moderate resistance to weathering	4.5
5. Arkosic wacke, medium-grained; moderately well sorted; very large-scale, parallel and low angle, cross bedding; moderate grayish yellow (5Y 7/4); slight resistance to weathering	4.2
4. Lithic wacke, fine-grained; very well sorted; small- and large-scale, low angle, cross laminations; bedded; light olive gray (5Y 5/2); moderate resistance to weathering; one bed of fine-grained arkosic arenite; well sorted; contains fossils; great resistance to weathering; fossils (transported): plants common; ?<u>Stagnicola</u> sp. rare; ?<u>Planorbula</u> aff. <u>P</u>. <u>armigera</u>	2.5
3. Arkosic arenite, medium-grained; moderately well sorted; grains very angular; subequant; large-scale, low angle, cross bedding; channels rare;	

SECTION 17 (cont.)

	concretions common; light olive gray (5Y 6/1); moderate resistance to weathering	3.3
2.	Arenite, fine-grained; interbedded with fine-grained wacke; light olive gray (5Y 5/2); slight resistance to weathering; fossils (<u>in situ</u>): stromatolites up to 15 cm in diameter	1.2
1.	Conglomerate, pebbly; very poorly sorted; large- and very large-scale, low angle, cross bedding; channels rare; moderate grayish yellow (5Y 7/4); moderate resistance to weathering	7.0
Total thickness		22.7

SECTION 18

Section 18 is about 200 m south of the Tumble Inn campground along the Old Ridge Route. The base of the section (NE¼SW¼NE¼ sec. 7, R. 7 N., T. 17 W.) begins on the inside of the first hairpin curve south of Tumble Inn campground on the west side of the road, and extends about 150 m southward along the road. Accession number 5741, Figure 11 (columnar section).

Top of section Unit		Thickness (metres)
6.	Conglomerate, pebbly; poorly sorted; large- and very large-scale, low angle, cross bedding; channels; coarsening upwards; light olive gray (5Y 6/1); moderate resistance to weathering	7.0
5.	Siltstone interbedded with very fine-grained wacke; small-scale, trough-shaped, grouped, cross bedding; light olive gray (5Y 5/2); slight resistance to weathering	2.9
4.	Lithic arenite, fine-grained; small-scale, low angle, trough-shaped, grouped, cross bedding; moderate resistance to weathering	0.8
3.	Wacke, very fine-grained; interbedded with silty claystone and clayey siltstone; sympathetic folding at base (from fault); light olive gray (5Y 5/2); slight resistance to weathering; fossils (transported): ?*Planorbula* aff. *P. armigera* rare . .	6.1

SECTION 18 (cont.)

2.	Conglomerate, pebbly; very poorly sorted; large-scale, parallel and low angle, cross bedding; parallel bedding near top; great resistance to weathering	5.2
1.	Wacke, very fine-grained; interbedded with fine-grained arenite; well sorted; increasing matrix upwards; fault with about 1 m offset (plane is horizontal); light olive gray (5Y 6/1); slight resistance to weathering	7.3
Total thickness	. . . .	29.3

SECTION 19

Section 19 is along the east side of Interstate 5. The base of the section (NW¼NW¼SE¼ sec. 29, T. 6 N., R. 17 W.) begins in a small unnamed canyon about halfway between Big Oak Flat and Fisher Spring. Accession numbers: 5697; 5743, Figure 12 (columnar section).

Top of section Unit		Thickness (metres)
10.	Sandstone, fine-grained; increasing matrix upwards; parallel laminations; moderate yellowish brown (10YR 5/4) to grayish orange (10YR 7/4)	1.0
9.	Siltstone; interbedded with claystone and very fine-grained sandstone; small-scale, cross laminations; olive gray (5Y 3/2) to grayish orange (10YR 7/4)	3.4
8.	Sandstone, coarse-grained; fining upwards to very fine-grained sandstone; low angle, planar, cross bedding in lower portion; grayish orange (10YR 7/4); fossils: plants (charcoal fragments)	4.0
7.	Siltstone; interbedded with very fine-grained sandstone; parallel and cross laminations; olive gray (5Y 3/2) to grayish orange (10YR 7/4); fossils: Musculium transversum abundant; Ostracoda . .	9.3
6.	Siltstone; interbedded with claystone and very fine-grained sandstone; parallel and cross laminations; olive gray (5Y 3/2); fossils: stromatolites; plants rare; Anodonta oregonensis common; Musculium	

SECTION 19 (cont.)

	transversum common; Ostracoda abundant; fish (Atherinidae or Cyprinodontidae) common; burrows rare	4.8
5.	Sandstone, fine-grained; mudstone clasts near base; large-scale, trough-shaped, cross bedding; dark yellowish orange (10YR 6/6); fining upwards to siltstone interbedded with claystone; olive gray (5Y 3/2); fossils: plants; Ostracoda common; burrows	2.9
4.	Claystone; interbedded with siltstone and very fine-grained sandstone; parallel and cross laminations; olive gray (5Y 3/2); fossils: plants rare	1.4
3.	Sandstone, very fine-grained; fining upwards to siltstone; dark yellowish brown (10YR 4/2); fossils: plants; Ostracoda rare; fish common; burrows rare	1.3
2.	Sandstone; medium-grained; fining upwards to fine-grained sandstone interbedded with siltstone; parallel laminations; grayish orange (10YR 7/4); fossils: plants rare; burrows rare	1.6
1.	Claystone; interbedded with siltstone; olive gray (5Y 3/2); fossils: plants rare	0.6
Total thickness		30.3

SECTION 20

Section 20 is west-southwest of a hill (elevation 3424) along the south side of the Old Ridge Route. The base of the section (SE¼NW¼NW¼ sec. 16, T. 6 N., R. 17 W.) begins near a canyon that intersects the road and the section extends westward for about 10 m. Accession number: 5695, Figure 12 (columnar section).

Top of section Unit	Thickness (metres)
1. Sandstone, medium-grained; pebbly with mudstone clasts near base; interbedded with siltstone; fossils: plants common; *Anodonta oregonensis* common	3.9
Total thickness	3.9

SECTION 21

Section 21 is about 2 km north of the Templin Highway exit along the east side of Interstate 5. The base of the section (SE¼SE¼NW¼ sec. 29, T. 6 N., R. 17 W.) is about 30 m east of the Interstate and extends northwestward. Accession number 5744, Figure 12 (columnar section).

Top of section Unit	Thickness (metres)
5. Siltstone; parallel laminations; olive gray (5Y 3/2); fossils: plants rare; burrows abundant	2.0
4. Sandstone, very fine-grained; interbedded with siltstone; parallel laminations; grayish orange (10YR 7/4); fossils: plants rare; burrows common . .	7.2
3. Siltstone; parallel bedding; olive gray (5Y 3/2); fossils: plants rare; *Anodonta oregonensis* abundant; Ostracoda abundant; burrows common	4.1
2. Sandstone, fine-grained; small-scale, high angle, cross laminations; dark yellowish orange (10YR 6/6) .	1.0
1. Sandstone, very fine-grained; interbedded with siltstone; parallel laminations; dark yellowish brown (10YR 4/2) to olive gray (5Y 3/2); fossils: Pelecypoda abundant; cyprid aff. *Heterocypris* sp. abundant; Charophyta; cladoceran ephippia; fish (either Atherinidae or Cyprinodontidae) common . . .	5.6
Total thickness	19.9

SECTION 22

Section 22 is on the south side of the Old Ridge Route. The base of the section (SW¼NW¼NW¼ sec. 29, T. 6 N., 17 W.) is about 1.2 km south 58° east of benchmark 3327 and extends northwestward. Accession numbers: 5698 - 5699, Figure 12 (columnar section).

Top of section

Unit		Thickness (metres)
6.	Sandstone, medium-grained; fining upwards; interbedded with siltstone and claystone; parallel laminations; moderate yellowish brown (10YR 5/4); fossils: plants rare; charcoal rare; Anodonta oregonensis abundant; burrows rare	1.7
5.	Claystone; interbedded with siltstone; fossils: Pelecypoda abundant; Cyprideis beaconensis common; Candona sp. common; burrows common	2.0
4.	Sandstone, medium-grained; small-scale, trough-shaped, cross bedding; fining upwards to fine-grained sandstone; interbedded with siltstone; parallel laminations; and claystone; dark yellowish brown (10YR 4/2); fossils: charcoal common; Anodonta oregonensis abundant; burrows abundant . . .	4.4
3.	Siltstone; parallel laminations and rare cross laminations; interbedded with claystone; olive gray (5Y 3/2); fossils: plants rare; burrows common	6.3
2.	Sandstone, fine-grained; parallel and cross laminations; fossils: charcoal abundant	0.6

SECTION 22 (cont.)

1. Siltstone; interbedded with claystone; small-scale, parallel and cross laminations; light olive gray (5Y 5/2); fossils: plants rare 1.5

Total thickness 16.5

SECTION 23

Section 23 is about 2.6 km north of the Templin Highway exit along the east side of Interstate 5. The base of the section (SE¼NW¼NW¼ sec. 29, T. 6 N., R. 17 W.) is on the slope between the first and second terraces. Accession number 5823, Figure 12 (columnar section).

Top of section Unit		Thickness (metres)
4.	Sandstone, fine-grained; in-erbedded with siltstone; fining upwards to siltstone; small-scale, cross laminations; grayish orange (10YR 7/4); fossils: burrows abundant	1.9
3.	Sandstone, medium-grained; trough-shaped, cross bedding; fining upwards to very fine-grained sandstone and siltstone; grayish orange (10YR 7/4); fossils: burrows common	1.8
2.	Sandstone, fine-grained; interbedded with siltstone; fining upwards to siltstone; parallel laminations; moderate yellowish brown (10YR 5/4); fossils: plants rare: charcoal rare; Anodonta oregonensis abundant; Ostracoda rare; burrows common .	12.5
1.	Siltstone; olive gray (5Y 3/2); fossils: plants rare; charcoal rare; Hypolagus sp. (rabbit tibia) rare; burrows rare	3.6
Total thickness		19.8

APPENDIX B

RELATIVE ABUNDANCE OF FOSSILS

RELATIVE ABUNDANCE OF FOSSILS

Refer to Figures 7-12 for stratigraphic occurrences and Plate 2 for locations. Abundance based on estimates of individuals per metre along strike.

Explanation of symbols:

A=more than 20 per metre; C=10-20 per metre; U=3-10 per metre; R=less than 3 per metre; ?=uncertain assignment; a four digit numeral = LACMNH accession (locality) number

Explanation of fossils:

stromat	stromatolites and oncolites
charoph	Charophyta
plant	wood, plant or charcoal fragments
chlamys	*Chlamys* (*Chlamys*) cf. *C.* (*C.*) *hodgei*
oregone	*Anodonta oregonensis*
lacustr	*Musculium lacustre*
transve	*Musculium transversum*
nitidum	*Pisidium* cf. *P.* (*Cyclocalyx*) *nitidum*
spherii	Spheriidae (not identifiable to family)
pelecyp	Pelecypoda (not identifiable to family)
fonteli	*Fontelicella* aff. *F.* (*F.*) *truckeensis*
tryonia	*Tryonia* aff. *T. protea*
hydro 1	Hydrobiidae species 1
hydro 2	Hydrobiidae species 2
stagnic	?*Stagnicola* sp.
planorb	?*Planorbula* aff. *P. armigera*
gastrop	Gastropoda (not identified to family)

beacone	*Cyprideis beaconensis*; *C.* aff. *C. beaconensis*
candona	*Candona* sp.
cypride	*Cyprideis* spp. (excluding *C. beaconensis*)
cythero	*Cytheromorpha* sp.
darwinu	*Darwinula* sp.
limnocy	*Limnocythere* spp. (excluding *L. ornata*)
ornata	*Limnocythere* aff. *L. ornata*
salinus	*Cyprinotus* aff. *C. salinus*
ostraco	Ostracoda (not identified to genus)
fish	fish remains (skeletons or scales)
merychi	*Merychippus* aff. *M. sumani*
burrows	burrows

TABLE 1

RELATIVE ABUNDANCE OF FOSSILS

LACMNH Loc. no.	fossils																											
	burrows	merychl	fish	ostraco	salinus	ornata	limnocy	darwinu	cythero	cypride	candona	beacone	gastrop	planorb	stagnic	hydro 2	hydro 1	tryonia	fontell	pelecyp	spherii	nitidum	transve	lacustr	oregone	chlamys	plant	charoph	stromat
5684				A														A											
5685												A						A											
5686				A														A											
5687				R														A											
5688												A						A											
5689	C											C						A											
5690	C											A				R		R	R										
5691				A												R		U	C								C		
5692				C													U		C									R	
5693	U											A				C	U	R	A									A	
5694				R															R										
5695																									C		C		
5696																									U				
5697	R		C	A																			C	C	C		R		?
5698	A																								A				
5699	R																								A				
5700			R							U				R		U			C				R	C					
5701													U										R	?			C		
5702															R						?								
5703																								C					U
5704			R	U											U								R		A				
5705																							R	R	A				
5706		R		R																	C								
5707																									R				
5708					R		R																		?				
5709				R										R	R								C	C	R				
5710																									U				
5711																				C	R								
5712																									U				A
5713					R						R												R				R		A
5714					A										R												R		
5715															U								A	A					
5716				R																			A						
5717				A										U									C	C			A		
5718				R										R	R								R				R		R
5719													U	R	A								R						
5720				R									U		A								R		R		A		
5721															R														C
5722				U										C	A							C	C	C			A		
5723				R									R	U	A							?	R		R		R		

TABLE 1--Continued

LACMNH Loc. no.	fossils																												
	burrows	merychi	fish	ostraco	salinus	ornata	limnocy	darwinu	cythero	cypride	candona	beacone	gastrop	planorb	stagnic	hydro 2	hydro 1	tryonia	fontell	pelecyp	spheril	nitidum	transve	lacustr	oregone	chlamys	plant	charoph	stromat
5724			R	R										C	C								C	R					
5725				A										C	U				A			A	C				U		
5726				U										A									R				U		
5727				U										A	C						R								
5728														A															
5729			R											A	R												U		
5730										A																			?
5731					C	C	C	C			C			A	R								?				U		
5732					C	C	C	C		C	C			A													U		
5733					C	C	C	C		C	C	C		C								R					U		
5734														C															
5735													C	R															
5736					C	C		C	C	C	C			C	U							R		U	C				
5737														R															
5738					A	A		A	A	A	A			A	U										A		U		
5739				A										A	U										A		U		
5740														?	R												C		
5741														R															
5742			R									A																	
5743																							A						
5744				A																					A		R		
5745																										R			
5823				R																					A				

APPENDIX C

FIELD NUMBER EQUIVALENTS OF LACMNH LOCALITY NUMBERS

TABLE 2

FIELD NUMBER EQUIVALENTS OF LACMNH LOCALITY NUMBERS

LACMNH loc. no.	Field nos. DY	AH	LACMNH loc. no.	Field nos. DY	AH
5684	012RB		5706	035RB	
5685	015RB		5707	036RB	
5686	016RB		5708	037RB	
5687	017RB		5709	038RB	
5688	022RB		5710	040RB	
5689	023RB		5711	041RB	
5690	024RB		5712	043RB	
5691	025RB		5713	046RB	
5692	026RB		5714	047RB	
5693	027RB		5715	049RB	
5694	028RB		5716	050RB	
5695	030RB	H-114	5717	051RB	
5696	011RB		5718	052RB	
5697	074RB	H-1017	5719	053RB	
5698	071RB	H-150	5720	054RB	
5699	072RB	H-157	5721	055RB	
5700	021RB		5722	056RB	
5701	020RB		5723	057RB	
5702	031RB		5724	058RB	
5703	032RB		5725	059RB	
5704	033RB		5726	060RB-A	
5705	034RB		5727	060RB-A	

REFERENCES CITED

REFERENCES CITED

Arnold, Ralph, 1909 [1910], Paleontology of the Coalinga district, Fresno and Kings Counties, California: United States Geological Survey Bulletin 396, p. 1-173.

Axelrod, D. I., 1950, The Piru George flora of southern California: Carnegie Institute Washington, Publication 590, p. 159-214.

Baker, F. C., 1928, The fresh water Mollusca of Wisconsin: Wisconsin Geological and Natural History Survey Bulletin 70, pt. 1, Gastropoda, p. 1-507; pt. 2, Pelecypoda, p. 1-495.

Barr, A. J., Goodnight, J. H., Sall, J. P., and Helwig, J. T., 1976, A user's guide to SAS 76: Raleigh, North Carolina, SAS Institute Incorporated, 329 p.

Bartsch, Paul, 1920, The West American mollusks of the families Rissoellidae and Synceratidae, and the rissoid genus Barleeia; United States National Museum, Proceedings, v. 58, p. 159-176.

Binney, W. G., 1865, Land and fresh-water shells of North America; pt. 3, Smithsonian Miscellaneous Collections, v. 7, no. 3 (serial no. 144), p. 1-120.

Bishop, E. E., and others, 1978, Suggestions to authors of the United States Geological Survey (6th ed.): Washington, U.S. Government Printing Office, 273 p.

Burch, J. B., 1975a, Freshwater Sphaeriacean clams (Mollusca: Pelecypoda) of North America: Hamburg, Michigan, Malacological Publishers, 96 p.

----- 1975b, Freshwater unionacean clams (Mollusca: Pelecypoda) of North America: Hamburg, Michigan, Malacological Publishers, 204 p.

Chamberlin, R. V., and Jones, D. T., 1929, A descriptive catalog of the Mollusca of Utah: Bulletin of the University of Utah, v. 19, no. 4 (Biological ser., v. 1, no. 1), p. 1-203.

Clarke, A. H., Jr., 1973, The freshwater molluscs of the Canadian Interior Basin: Malacologia, v. 13, no. 1 and 2, p. 1-509.

Clements, Thomas, 1937, Structure of southeastern part of Tejon Quadrangle, California: Bulletin of the American Association of Petroleum Geologist, v. 21, no. 2, p. 212-232.

Compton, R. R., 1962, Manual of field geology: New York: John Wiley, 378 p.

Conrad, T. A., 1855, Description of a new species of Melania: Academy of Natural Sciences of Philadelphia, Proceedings, v. 7, p. 269.

Crowell, J. C., 1950, Geology of Hungry Valley area, Southern California: Bulletin of the American Association of Petroleum Geologists, v. 34, p. 1623-1646.

----- 1954, Geologic map of the Ridge Basin Area, California: California Division of Mines and Geology Bulletin 170, map sheet 7, scale approximately 1: 100,000.

----- 1973, Ridge Basin, Southern California, in Sedimentary facies changes in Tertiary rocks, California Transverse, and Southern Coast Ranges: Society of Economic Paleontologists and Mineralogists, Pacific Section, Guidebook, Trip 2, p. 1-7.

----- 1974, Sedimentation along the San Andreas fault, California, in Dott, R. H., Jr., and Saver, R. H., eds., Modern and ancient geosynclinal sedimentation: Society of Economic Paleontologists and Mineralogists Special Publication 19, p. 292-303.

----- 1975, The San Gabriel fault and Ridge Basin, Southern California, in Crowell, J. C., ed., San Andreas fault in Southern California: California Division of Mines and Geology Special Report 118, p. 208-233.

David, L. B., 1945, A Neogene stickleback from the Ridge Formation of California: Journal of Paleontology, v. 19, p. 315-318.

Dehlinger, Peter, 1952, Geology of southern Ridge Basin, Los Angeles County, California: California Division of Mines and Geology Special Report 26, 11 p.

Dott, R. H., Jr., 1964, Wacke, graywacke and matrix-what approach to immature sandstone classification?: Journal of Sedimentary Petrology, v. 34, no. 3, p. 625-632.

Eaton, J. E., 1939, Ridge Basin, California: American Association of Petroleum Geologists Bulletin, v. 23, p. 517-558.

Ellis, A. E., 1962, British freshwater bivalve mollusks with keys and notes for the identification of the species, in Synopses of the British Fauna: Linnaean Society of London, v. 13, 92 p.

Ensley, R. A., and Verosub, K. L., 1979, Preliminary correlation of the Pliocene Ridge Basin Group of Los Angeles County, California, with the magnetic polarity time scale: Geology Society of America, Abstracts with Programs, v. 11, no. 2, p. 421.

Folk, R. L., 1974, Petrology of sedimentary rocks: Austin, Texas, Hemphill Publishing Company, 182 p.

Forester, Richard, 1979, 1980, United States Geological Survey, Denver, written communications.

Fuller, S. L. H., 1974, Clams and Mussels (Mollusca: Bivalvia), in Hart, C. W., Jr., and Fuller, S. L. H., eds., Pollution ecology of freshwater invertebrates: New York and London, Academic Press, p. 215-273.

Gale, W. F., 1977, Growth of the fingernail clam, Sphaerium transversum (Say) in field and laboratory experiments: Nautilus, v. 91, p. 8-12.

Goddard, E. N., and others, 1963, Rock-color chart: National Research Council; reprinted by Geological Society of America, 1951, 1963, 1970, 6 p.

Gould, A. A., 1855, New species of land and fresh-water shells from western (N.) America: Boston Society of Natural History, Proceedings, v. 5, p. 127-130.

Gregg, W. O., 1947, The fresh water Mollusca of California, including a few forms found in adjoining areas: Minutes of the Conchological Club of Southern California, no. 67, p. 3-21; no. 69, p. 3-18; no. 70, p. 14-20.

Gregg, W. O., and Taylor, D. W., 1965, Fontelicella (Prosobranchia: Hydrobiidae), a new genus of west American freshwater snails: Malacologia, v. 3, p. 103-110.

Grenda, J. C., 1977, Paleozoology of cores from the Tyler Formation (Pennsylvanian) in North Dakota, U.S.A.: University of North Dakota, Ph.D. dissertation, 338 p.

Hanna, G. D., 1922, Fossil freshwater mollusks from Oregon contained in the Condon Museum of the University of Oregon: University of Oregon Publications, v. 1, no. 12, p. 1-22.

Hannibal, H. B., 1912, A synopsis of the recent and Tertiary freshwater Mollusca of the Californian province, based upon an ontogenetic classification: Malacological Society of London, Proceedings, v. 10, p. 112-211.

Harper, Andrew, 1978-1980, University of Southern California, Department of Geological Sciences, written communications.

Heard, W. H., 1977, Reproduction of fingernail clams (Sphaeriidae; Sphaerium and Musculium): Malacologia, v. 16, p. 421-455.

Hemphill, Henry, 1891, A collector's notes on variation in shells, with some new varieties: Zoe, v. 1, p. 321-337.

Henderson, Junius, 1924, Mollusca of Colorado, Utah, Montana, Idaho and Wyoming: The University of Colorado Studies, v. 13, p. 65-223.

Herrington, H. B., 1962, A revision of the Sphaeriidae of North America (Mollusca: Pelecypoda): Miscellaneous Publications of the Museum of Zoology, University of Michigan, no. 118, p. 1-74.

Irvine, P. J., 1977, The Posey Canyon Shale, a Pliocene lacustrine deposit of the Ridge Basin, southern California: University of California, Berkeley, Masters thesis, 97 p.

Jones, D. T., 1940, Recent collections of Utah Mollusca, with extralimital records from certain Utah cabinets: Utah Academy of Sciences, Arts and Letters, Proceedings, v. 17, p. 33-45.

Keep, Josiah, 1911, West coast shells: San Francisco, Whitaker and Ray-Wiggin Company, 346 p.

Keep, Josiah, and Baily, J. L., Jr., 1935, West coast shells: Stanford, Stanford University Press, 350 p.

La Rocque, Aurèle, 1966-1970, Pleistocene Mollusca of Ohio: Ohio Geological Survey Bulletin 62, p. 1-800.

Lea, Isaac, 1838, Description of new freshwater and land shells: Philadelphia, Pennsylvania, Transactions of the American Philosophical Society, v. 6, p. 1-111.

Link, M. H., 1978-1980, Los Angeles Harbor College, Department of Geology, oral communications.

Link, M. H., and Osborne, R. H., 1978, Lacustrine facies in the Pliocene Ridge Basin Group: Ridge Basin, California, in Matter, Albert, and Tucker, M. E., eds., Modern and Ancient Lake Sediments: International Association of Sedimentologist Publication no. 2, p. 169-187.

Link, M. H., Osborne, R. H., and Awramik, Stanley, 1978, Lacustrine stromatolites and associated sediments of the Pliocene Ridge Route Formation, Ridge Basin, California: Journal of Sedimentary Petrology, v. 48, no. 1, p. 143-158.

Martin, P. S., and Mehringer, P. J., Jr., 1965, Pleistocene pollen analysis and biogeography of the southwest, in Wright, H. E., Jr., and Frey, D. G., eds., The Quaternary of the United States: Princeton, Princeton University Press, p. 433-451.

Miller, W. E., and Downs, Theodore, 1974, A Hemphillian fauna containing a new genus of antilocaprid from southern California: Natural History Museum, Los Angeles County, Contributions in Science, no. 258, p. 1-36.

Mullineaux, D. R., Waldron, H. H., and Rubin, Meyer, 1965, Stratigraphy and chronology of late interglacial and early Vashon glacial time in the Seattle area, Washington: United States Geological Survey Bulletin 1194-O, p. 1-110.

Nilsen, T. H., Bartow, J. A., Stump, Edmund, and Link, M. H., 1977, New occurrences of dish structures in the stratigraphic record: Journal of Sedimentary Petrology, v. 47, 1299-1304.

Oakeshott, G. B., 1971, California's changing landscape: San Francisco, McGraw Hill, 388 p.

Ortmann, A. E., 1913-1916, Studies in naiades: The Nautilus, v. 27, p. 88-91; v. 28, p. 20-22, 28-34, 41-47, 65-69, 106-108, 129-131, 141-143; v. 29, p. 63-67; v. 30, p. 54-57.

Pilsbry, H. A., 1891, Land and fresh-water mollusks collected in Yucatan and Mexico: Academy of Natural Sciences of Philadelphia, Proceedings, v. 43, p. 320-334.

Powers, M. C., 1953, A new roundness scale for sedimentary particles: Journal of Sedimentary Petrology, v. 23, p. 117-119.

Roscoe, E. J., 1961, Preliminary checklist of Lake Bonneville Mollusca: Sterkiana, no. 4, p. 23-28.

Russell, R. H., 1971, Mollusca of Fish Springs, Juab County, Utah: rediscovery of Stagnicola pilsbryi: The Great Basin Naturalist, v. 31, p. 223-236.

Say, Thomas, 1821, Descriptions of univalve shells of the United States: Journal of the Academy of Natural Sciences of Philadelphia, v. 2, p. 149-179.

Selley, R. C., 1970, Ancient sedimentary environments: Ithaca, New York, Cornell University Press, 237 p.

Simpson, C. T., 1914, A descriptive catalogue of the naiades, or pearly fresh-water mussels: Detroit (privately printed), 1540 p.

Squires, R. L., 1979, Middle Pliocene dragonfly nymphs: Ridge Basin, Transverse Ranges, California: Journal of Paleontology, v. 53, no. 2, p. 446-452.

Stearns, R. E. C., 1901, The fossil fresh-water shells of the Colorado Desert, their distribution, environment, and variation: United States National Museum, Proceedings, v. 24, p. 271-299.

Stimpson, William, 1865, Researches upon the Hydrobiinae and allied forms; chiefly made upon materials in the museum of the Smithsonian Institution: Smithsonian Miscellaneous Collections, v. 7, no. 4 (serial no. 201), p. 1-59.

Taylor, D. W., 1950, Three new Pyrgulopsis from the Colorado Desert, California: Leaflets in Malacology, v. 1, p. 27-33.

----- 1954, Nonmarine mollusks from the upper Miocene Barstow Formation, California: United States Geological Survey Professional Paper 254-C, p. 67-80.

----- 1960, Late Cenozoic molluscan faunas from the High Plains: United States Geological Survey Professional Paper 337, p. 1-94.

----- 1966a, A remarkable snail fauna from Coahuila, Mexico: The Veliger, v. 9, p. 152-228.

----- 1966b, Summary of North American Blancan nonmarine mollusks: Malacologia, v. 4, p. 1-172.

Taylor, D. W., and Sohl, N. F., 1962, An outline of gastropod classification: Malacologia, v. 1, no. 1, p. 7-32.

Webb, S. D., 1979, Curator of Vertebrate Paleontology, Florida State Museum, Gainesville, Florida, written communication.

Wilson, Edward, 1978, Curator of Invertebrate Paleontology, Los Angeles County Museum of Natural History, oral communication.

Yen, J. T., 1950, A molluscan fauna from the type section of the Truckee Formation: American Journal of Science, v. 248, p. 180-193.

PLATE 2

LOCATION OF MEASURED SECTIONS AND COLLECTING LOCALITIES

Dan Young, 1980

Modified United States Geological Survey 7.5 Minute Quadrangles:

Liebre Mtn., California, 1958 (photorevised 1974)

Whitaker Peak, California, 1958 (photorevised 1974)

Location of Plate 2 shown on figure

Contour interval 40 feet

0 1 2
kilometres

EXPLANATION

Delineation of measured sections

5789 LACMNH-IP locality number

2 Measured section number